What next? Potential species replacements for black ash in northern Minnesota in a changing climate

Black Ash Symposium

Bemidji, MN

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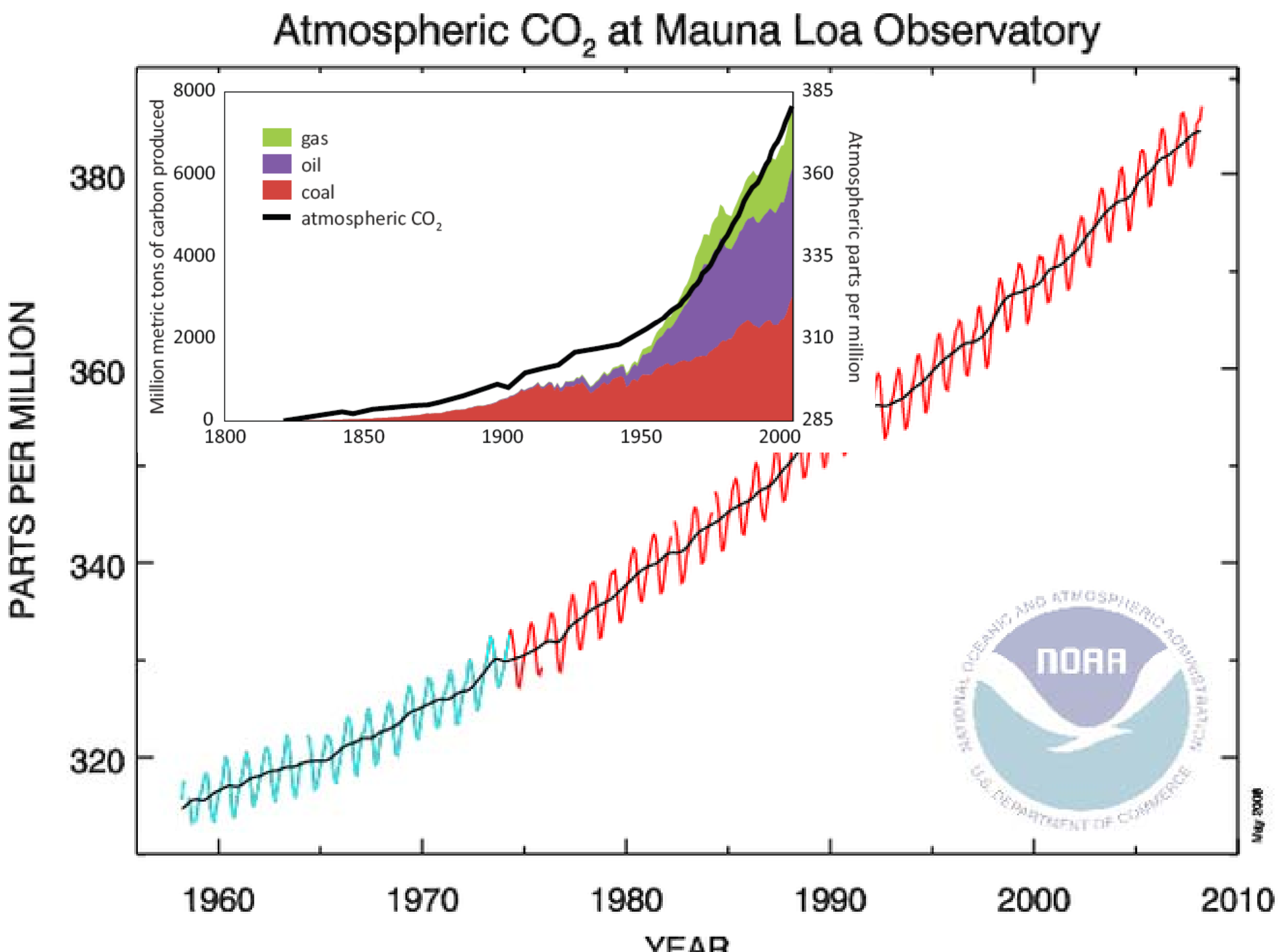
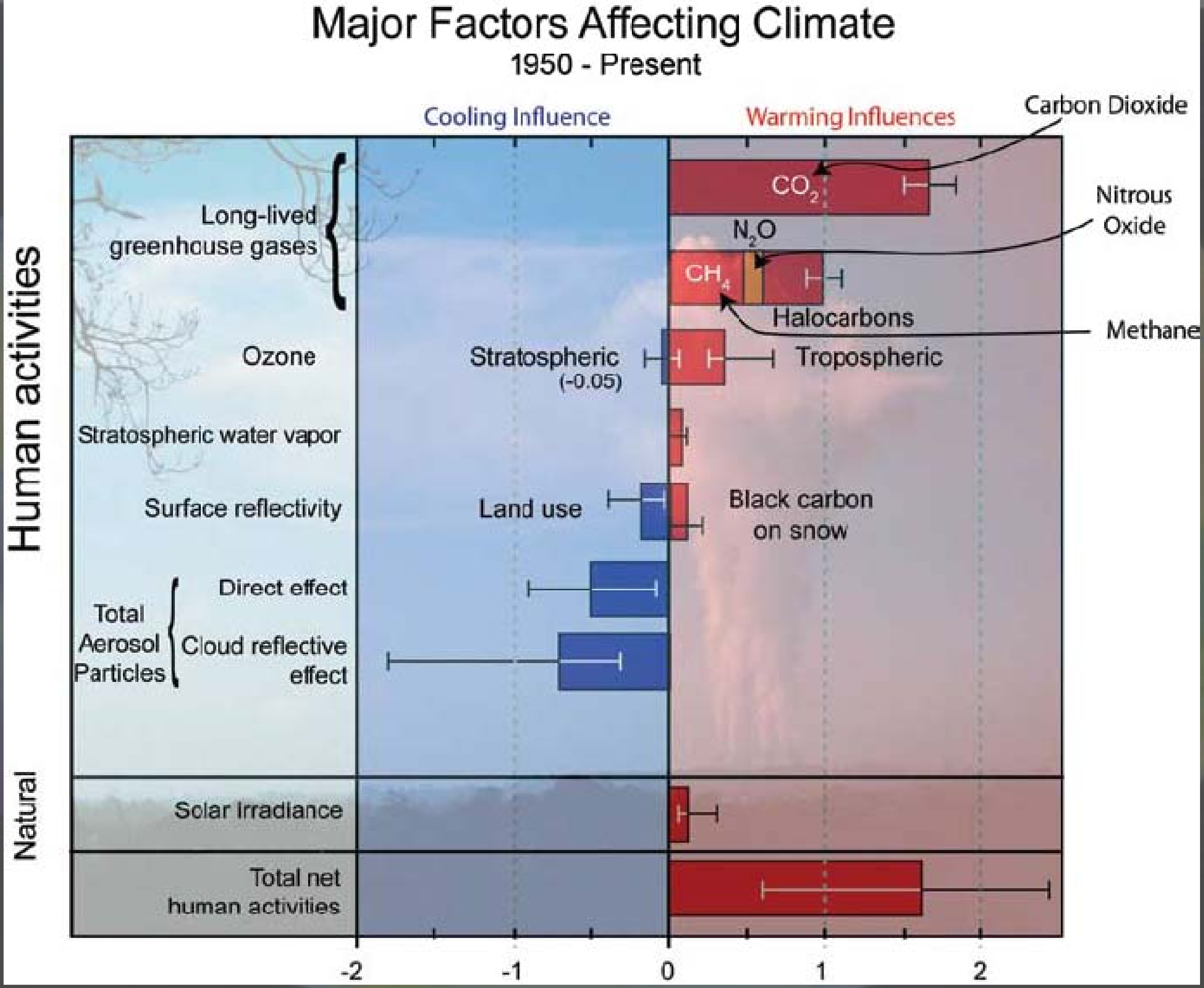
Outline

- Some general climate trends
- Overview of our climate change modeling approach
- Potential species habitat changes by 2100
- Evaluation of MN FIA data
- Evaluation of Ohio and Michigan plots
- Summary of possible replacements for black ash

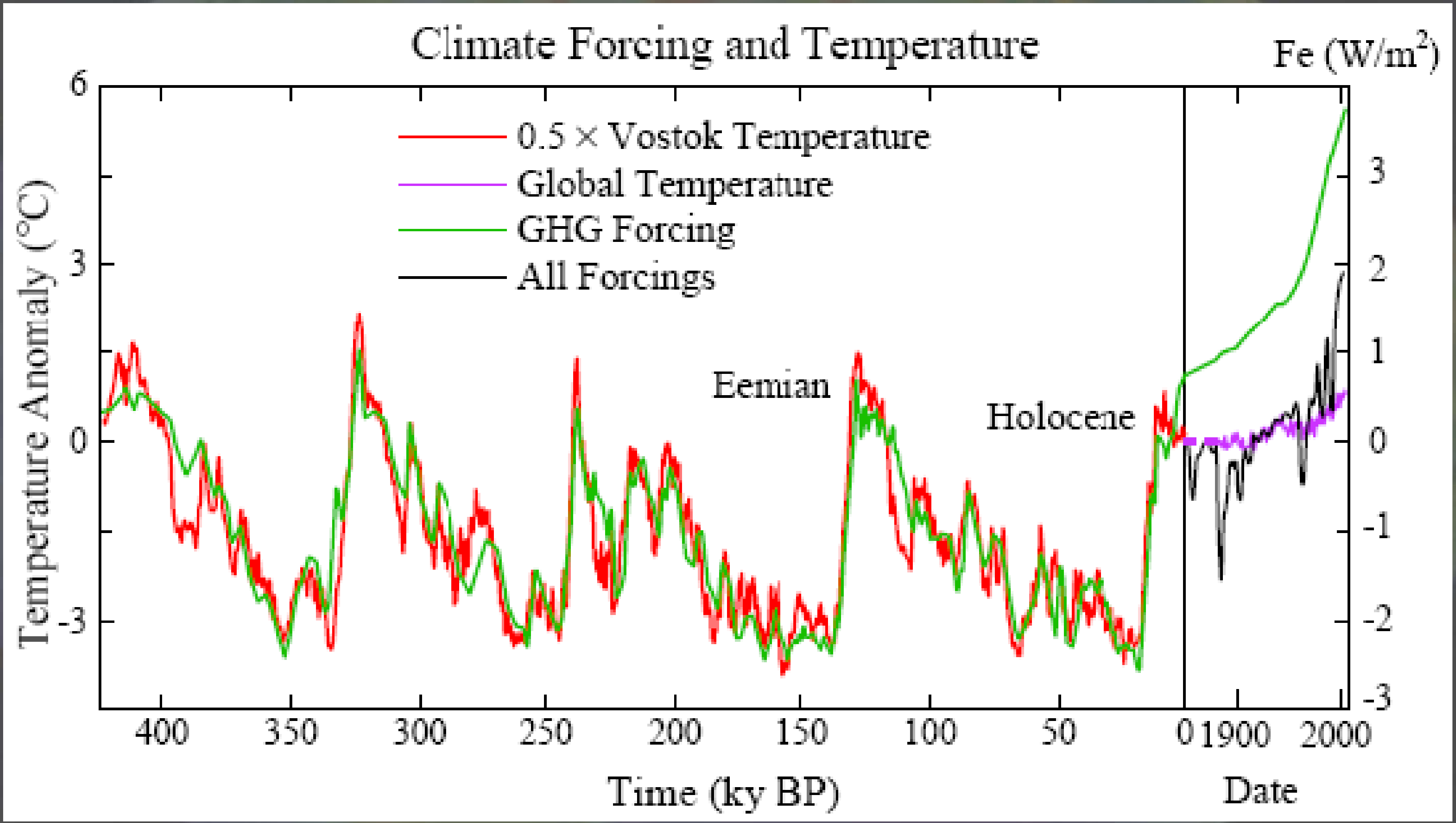
~2 ppm rise per year, now at 387 ppm = 100 ppm more than in 1860



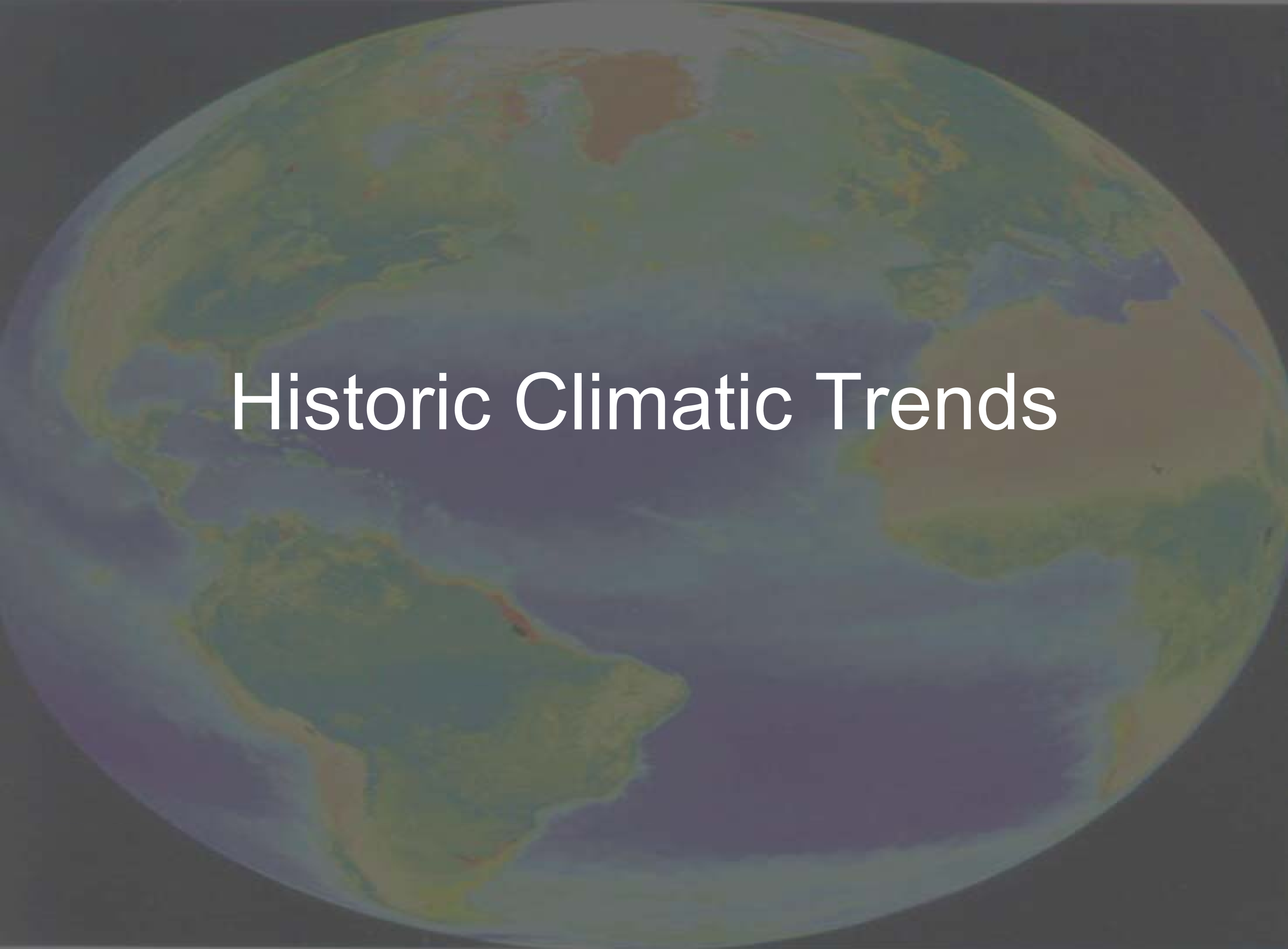


Major Factors Affecting Climate
1950 - Present
Cooling Influence
Warming Influences
Carbon Dioxide
Nitrous Oxide
Methane
Human activities
Long-lived greenhouse gases
CO_2
N_2O
CH_4
Halocarbons
Ozone
Stratospheric (-0.05)
Tropospheric
Stratospheric water vapor
Surface reflectivity
Land use
Black carbon on snow
Total Aerosol Particles
Direct effect
Cloud reflective effect
Natural
Solar Irradiance
Total net human activities
-2
-1
0
1
2

Hansen 2008

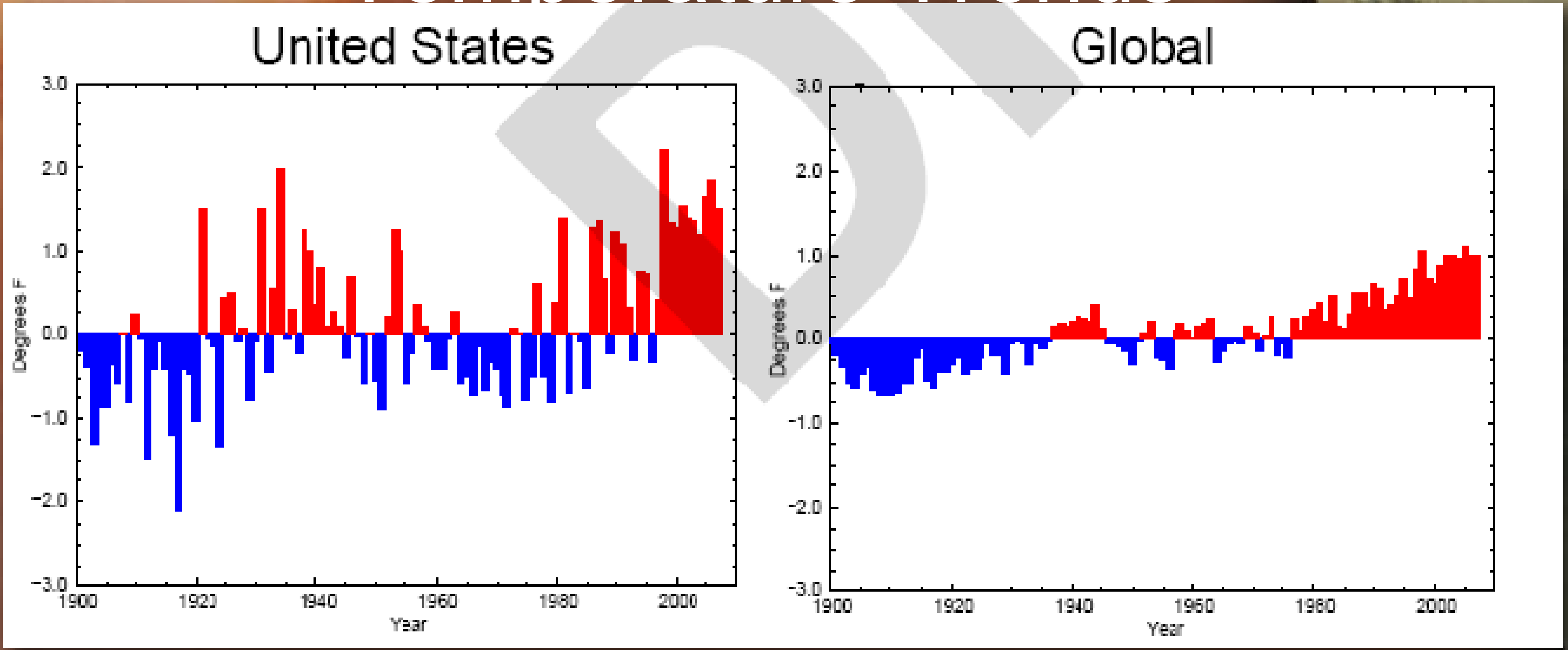

Climate Forcing and Temperature
Fe (W/m2)
0.5 × Vostok Temperature
Global Temperature
GHG Forcing
All Forcings
Eemian
Holocene
Temperature Anomaly (°C)
6
3
0
-3
3
2
1
0
-1
-2
-3
400
350
300
250
200
150
100
50
0
1900
2000
Time (ky BP)
Date

Hansen 2008



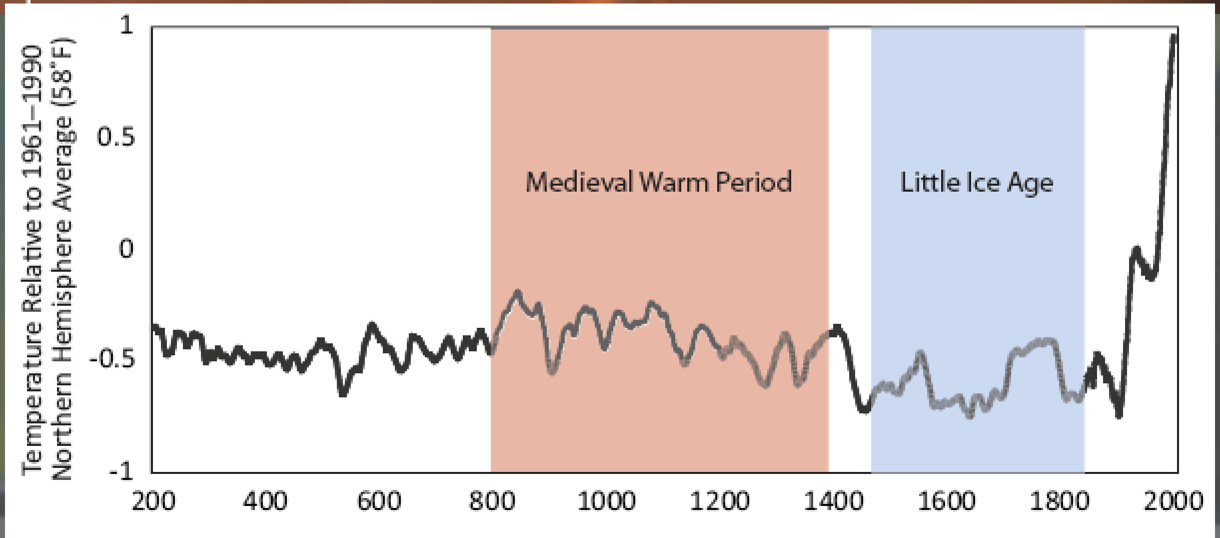
Historic Climatic Trends

Temperature Trends



Annual average temperatures compared to mean baseline.

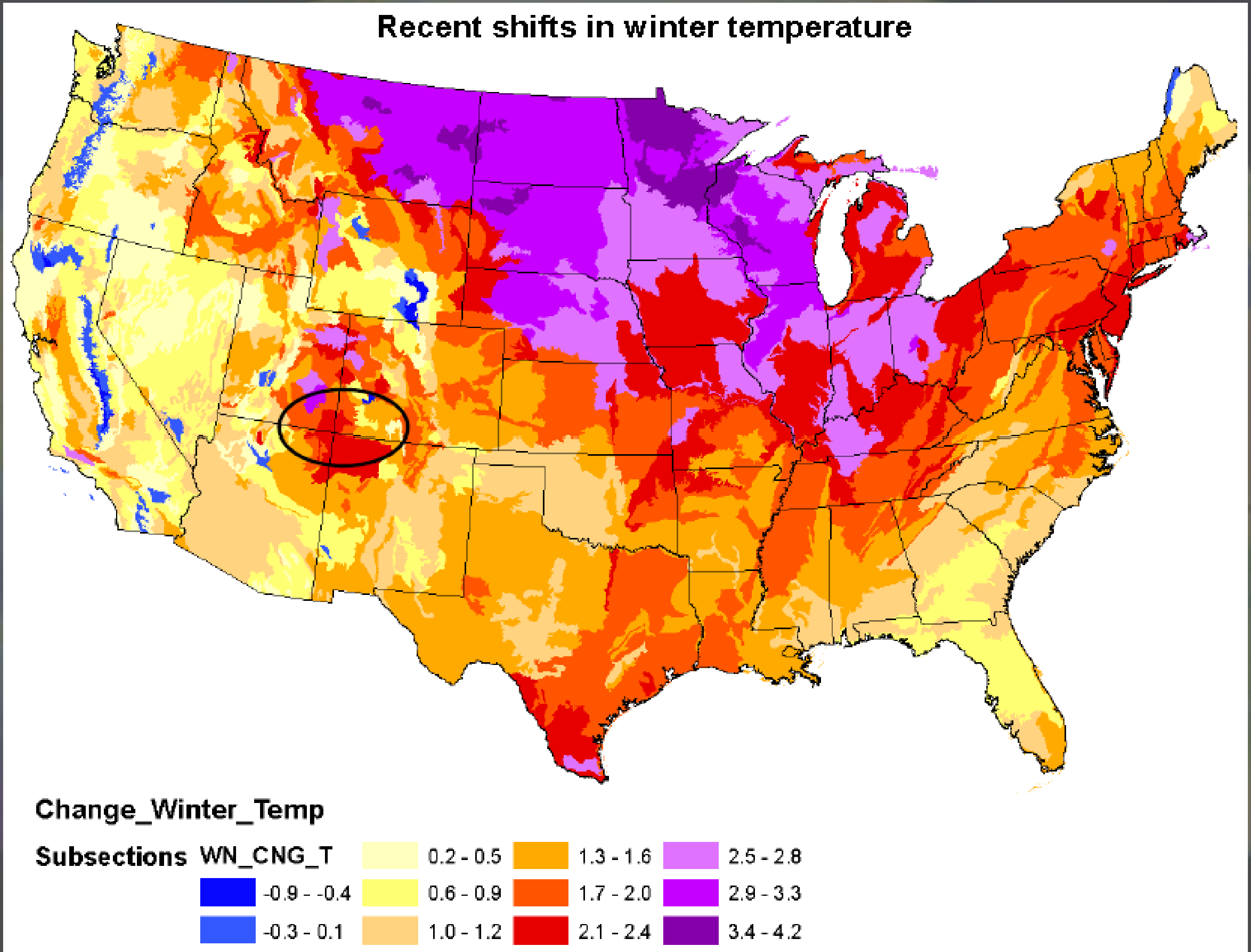
NOAA, 2009



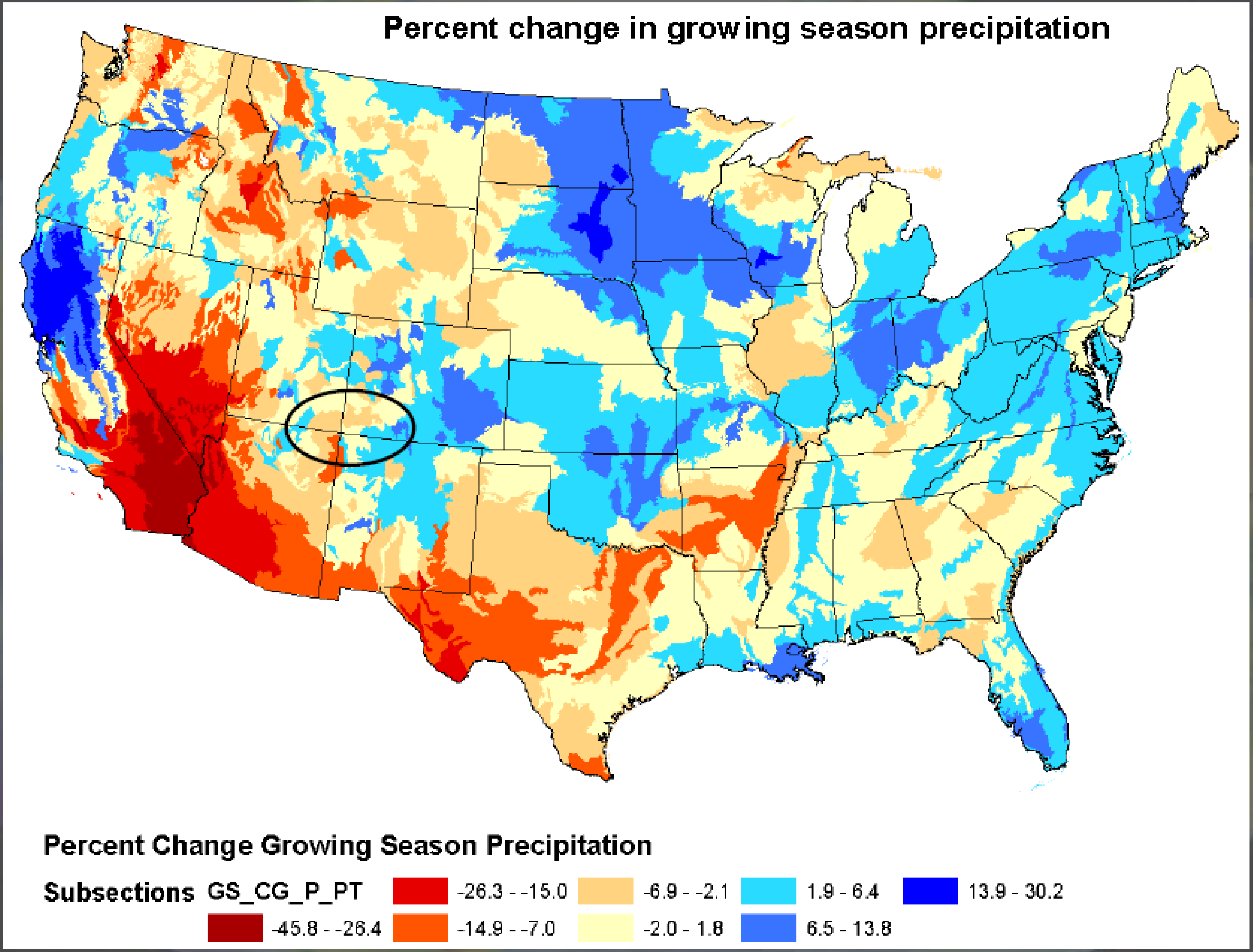
Recent shifts in climatic regimes

Comparison of components of climatic regimes of the 1961-1990 versus 1991-2007 periods

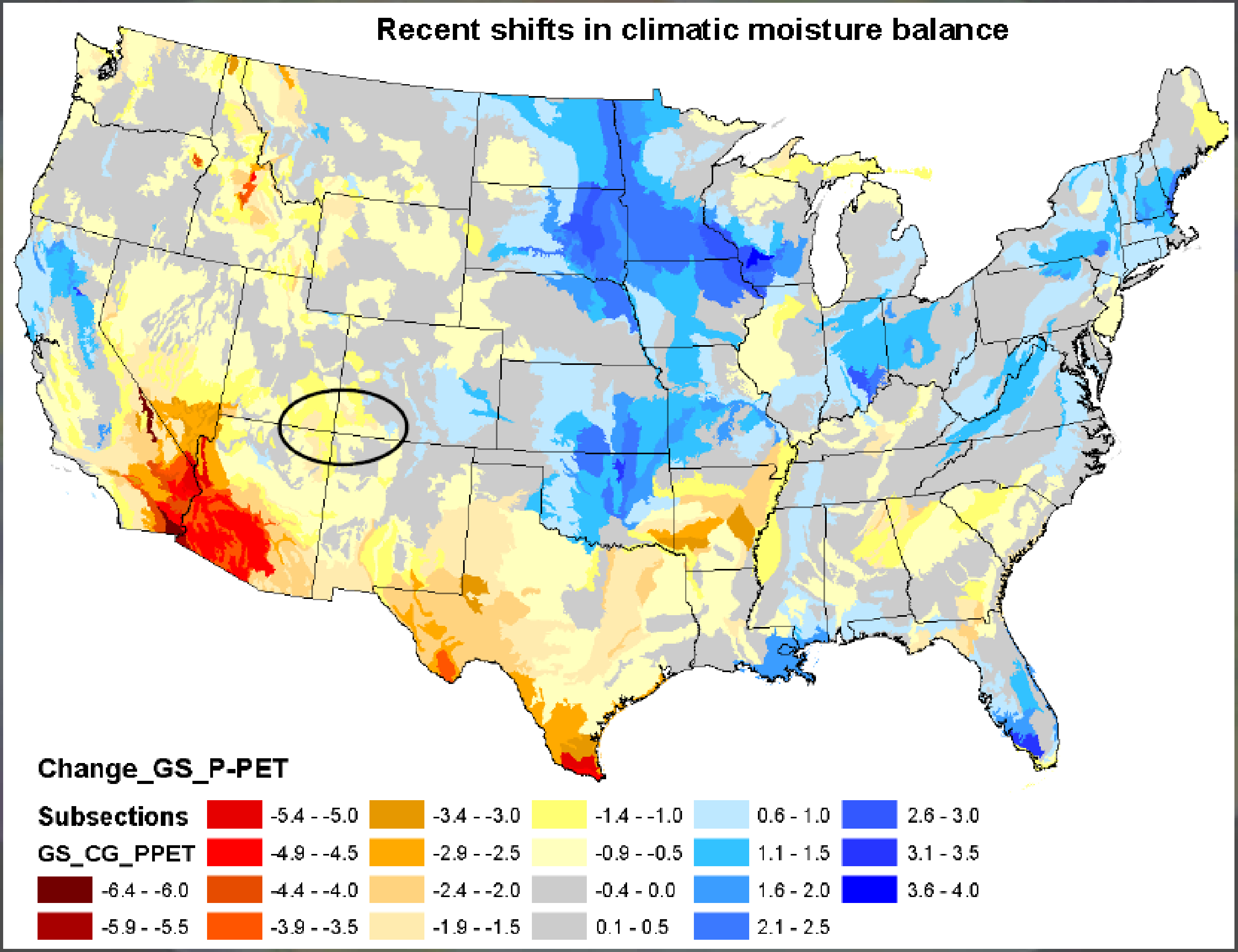
From Dave Cleland, USFS, 2010



From Dave Cleland, USFS, 2010



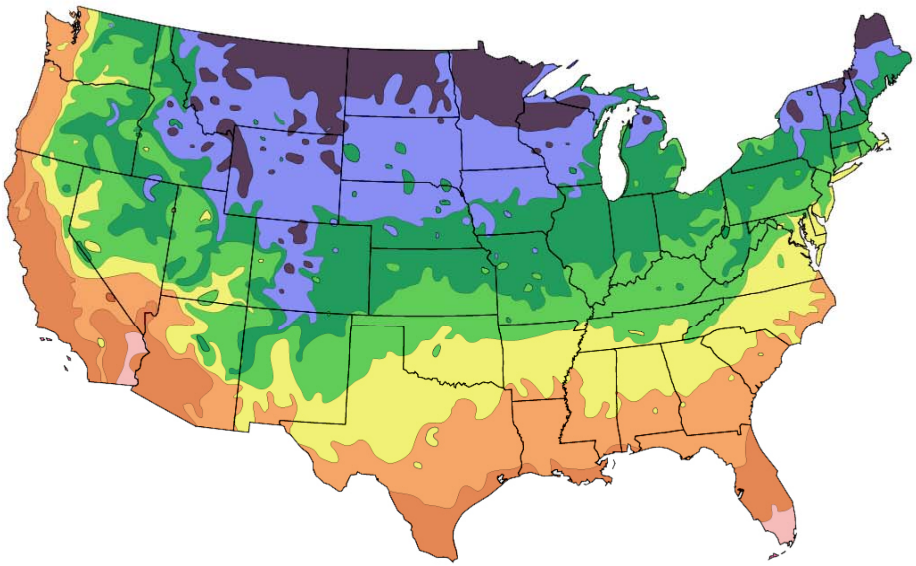
From Dave Cleland, USFS, 2010



From Dave Cleland, USFS, 2010

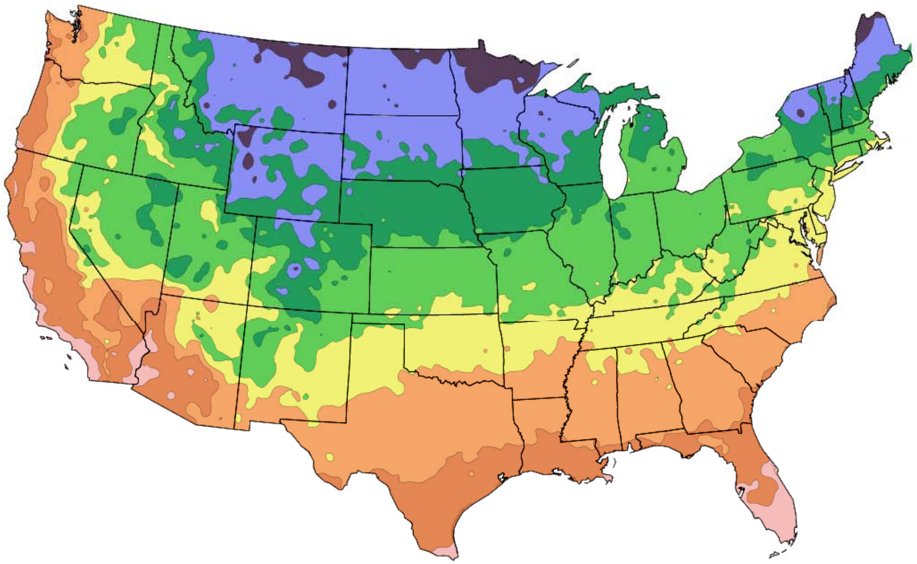
Plant Hardiness Maps

1990 Map

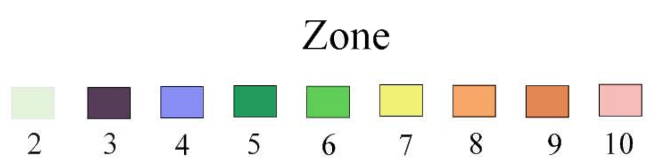


After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued Janua(r)y 1990

2006 Map



National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.



Responses to warming temperatures seen in more than 26,000 physical and biological systems around the world.

Montana’s Glacier National Park

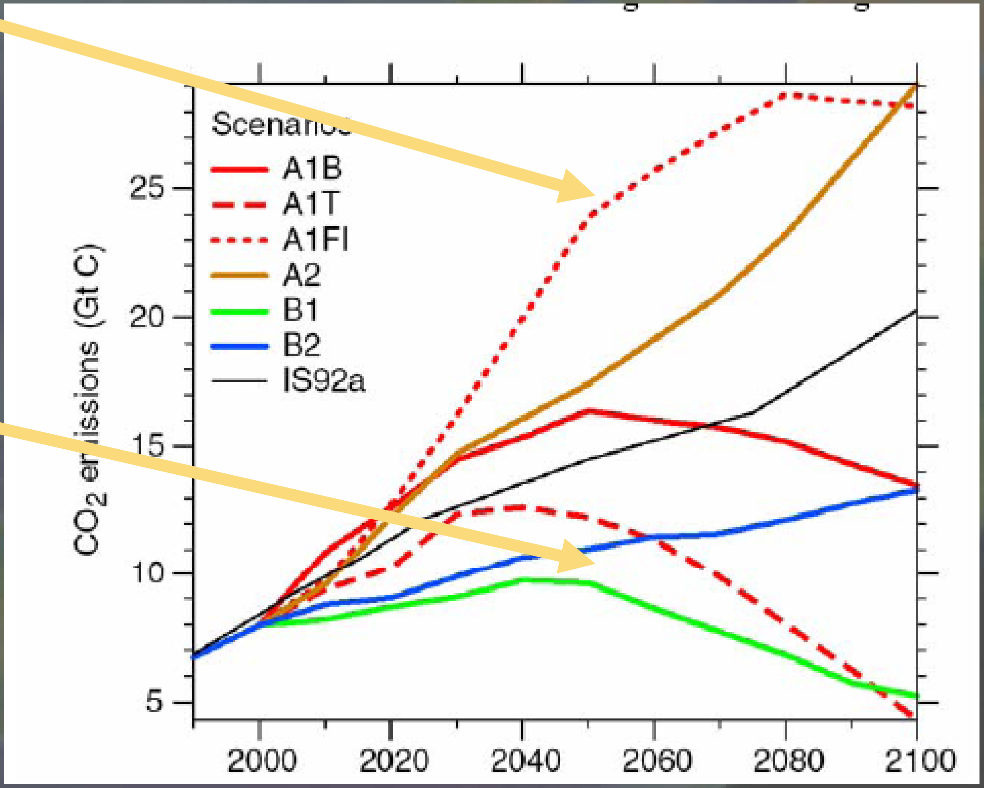
1910: 150 glaciers; Today: 30 glaciers

Future effects

Highly tied to the level of CO_2 emissions

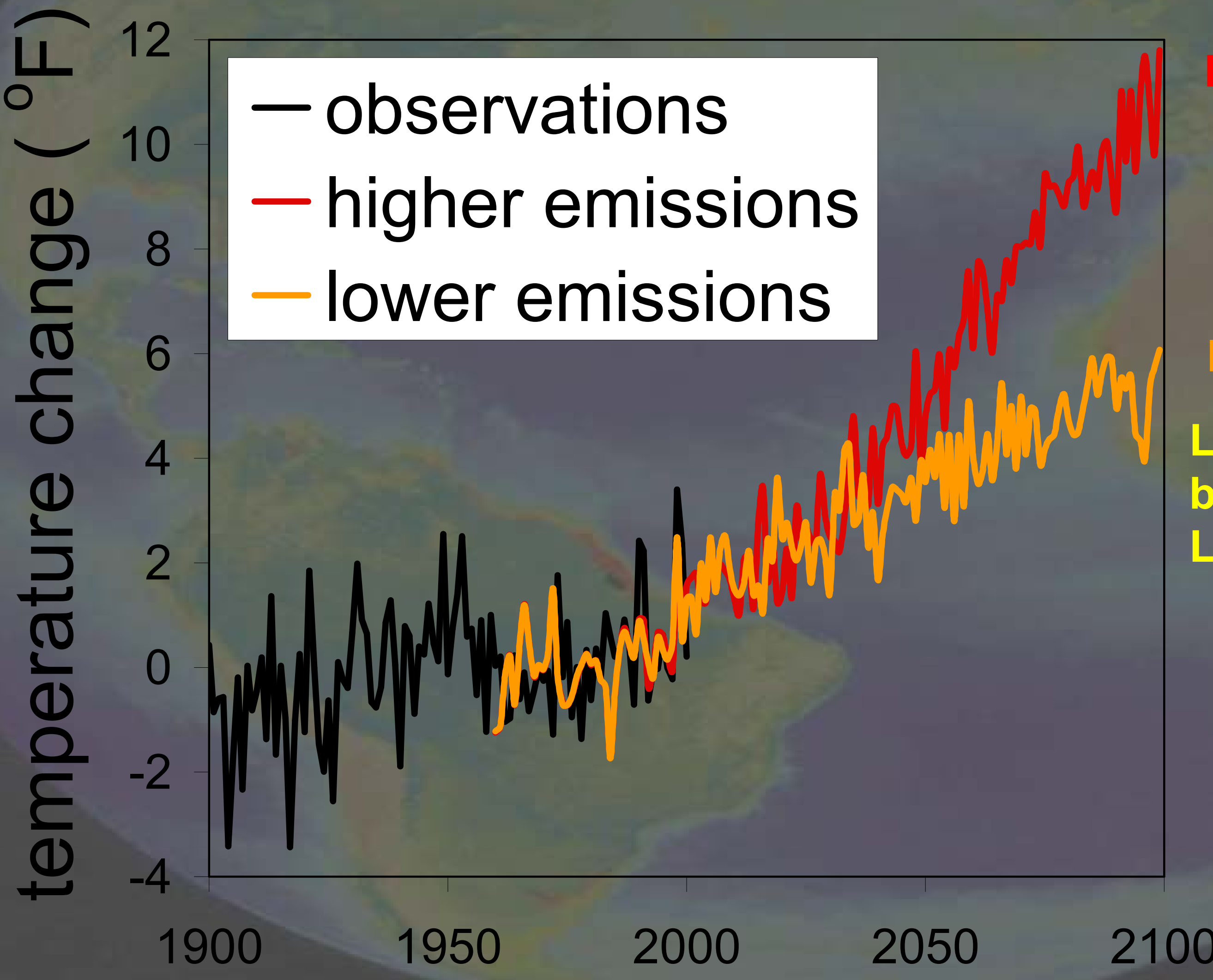
Emissions of CO_2 – range of scenarios over next 100 years

- A1fi (high)-fossil fuel intensive until later century
- B1 (low)-shift to resource efficient technology



Rising Temperatures in E. US

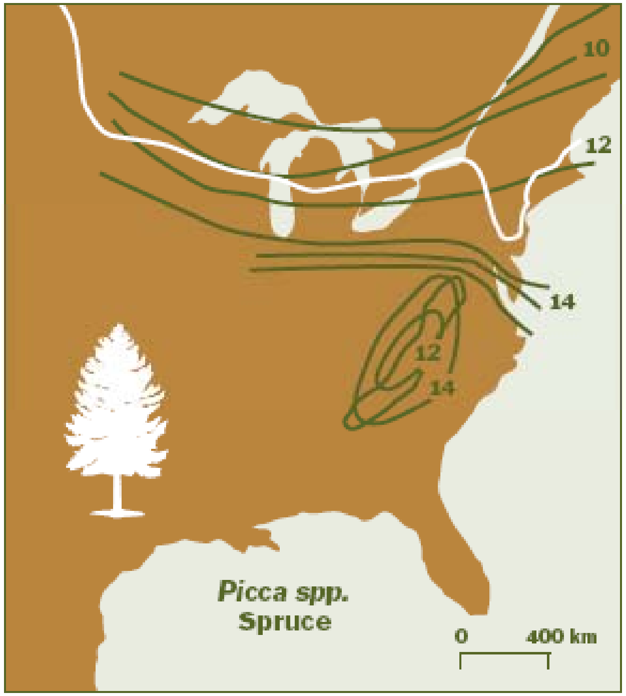
(annual average)

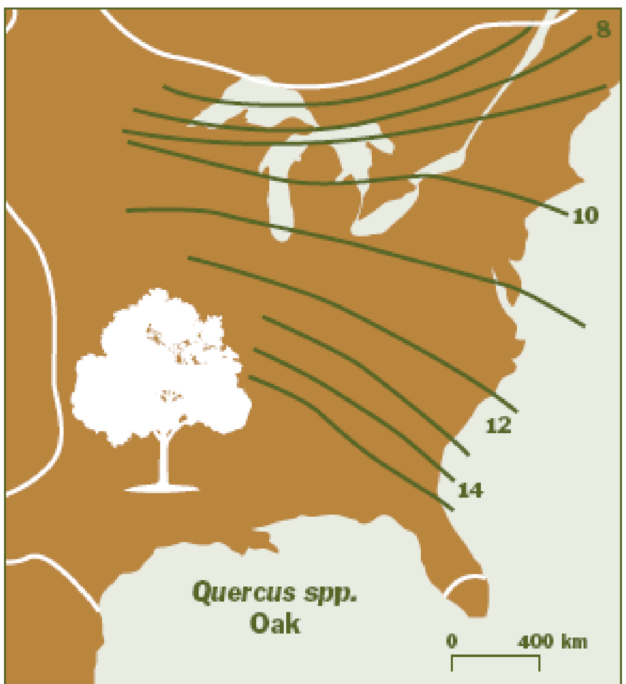


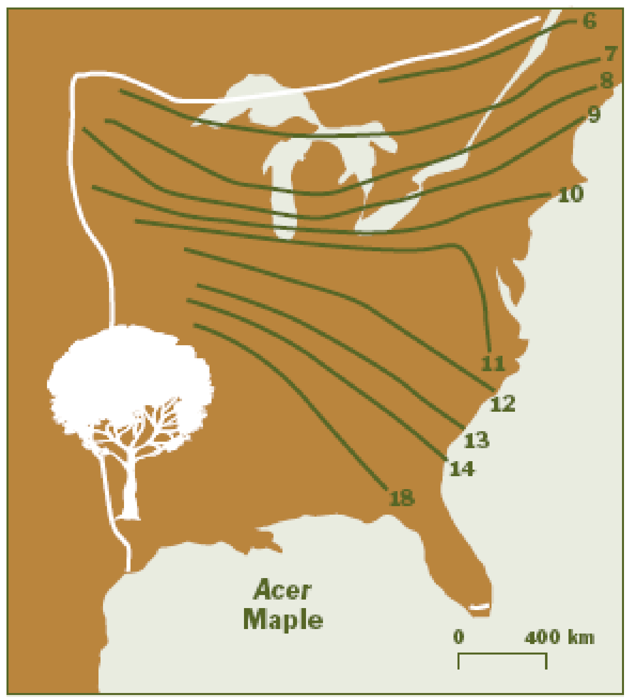
Higher: 6.5-12.5°F

Lower:3.5-6.5°F

Large difference between High and Low emissions!





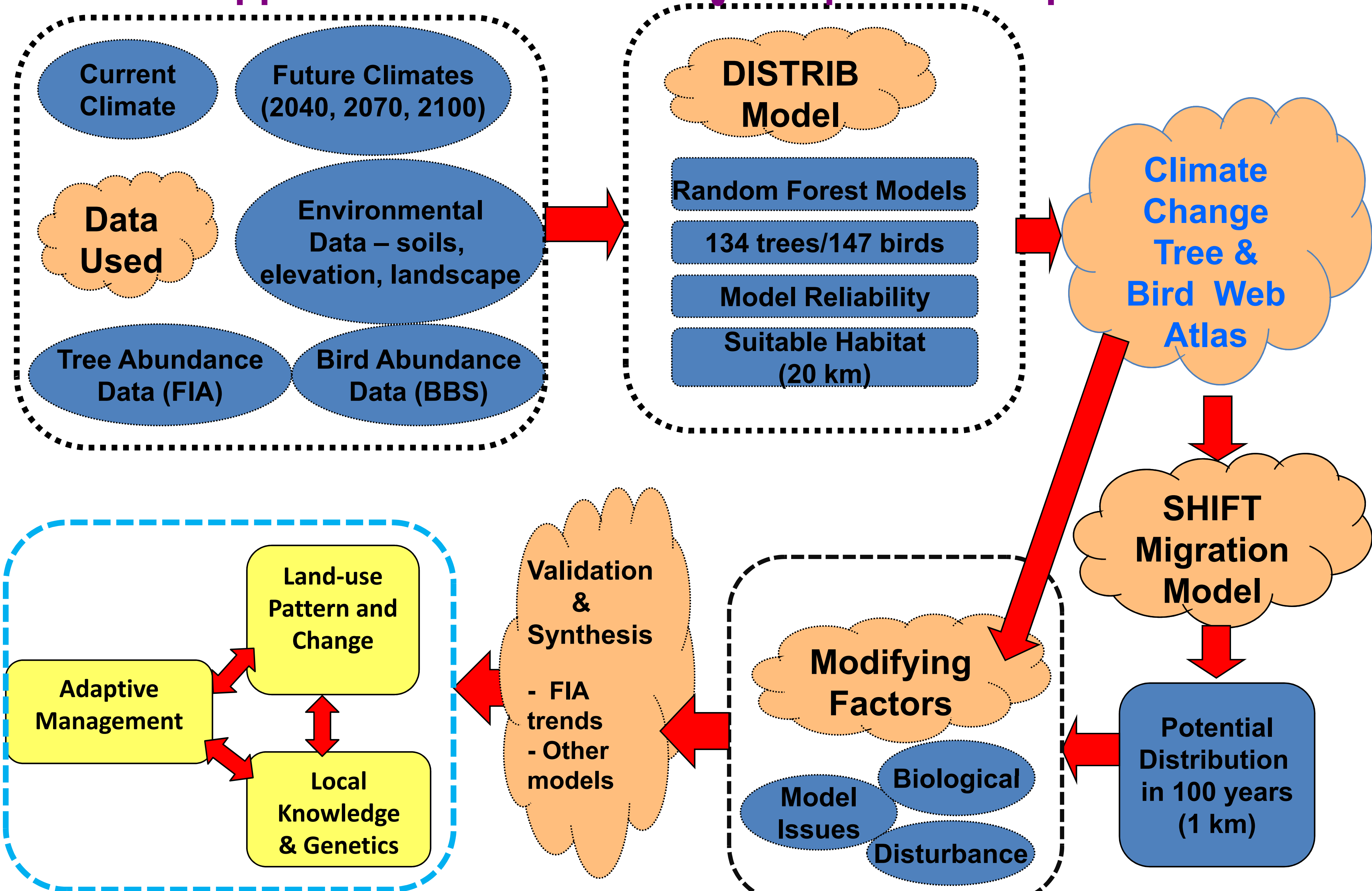


- **During the Holocene, which began 10-12k yrs ago, the avg. global temperatures increased by about 2 deg C.**
- **This warming is at the low end of IPCC, 2007 projections for 2100 !!!**

How's present-day vegetation going change with such rapid climate change + human-landuse disturbance ?!?

Source: Davis, 1981.

Our Approach: Climate Change Impacts on Species



Assembling responses

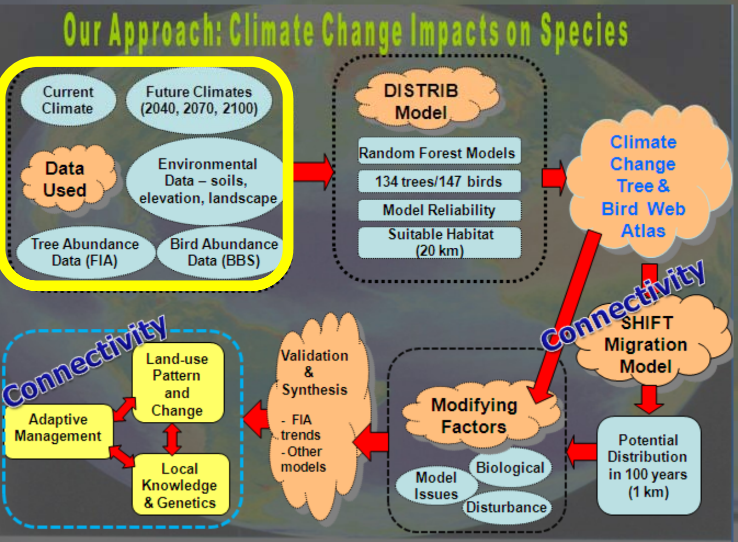
Forest Inventory and Analysis (FIA)

- 37 states east of 100th meridian
- 134 tree taxa
- 103,488 plots
- 2,938,518 tree records

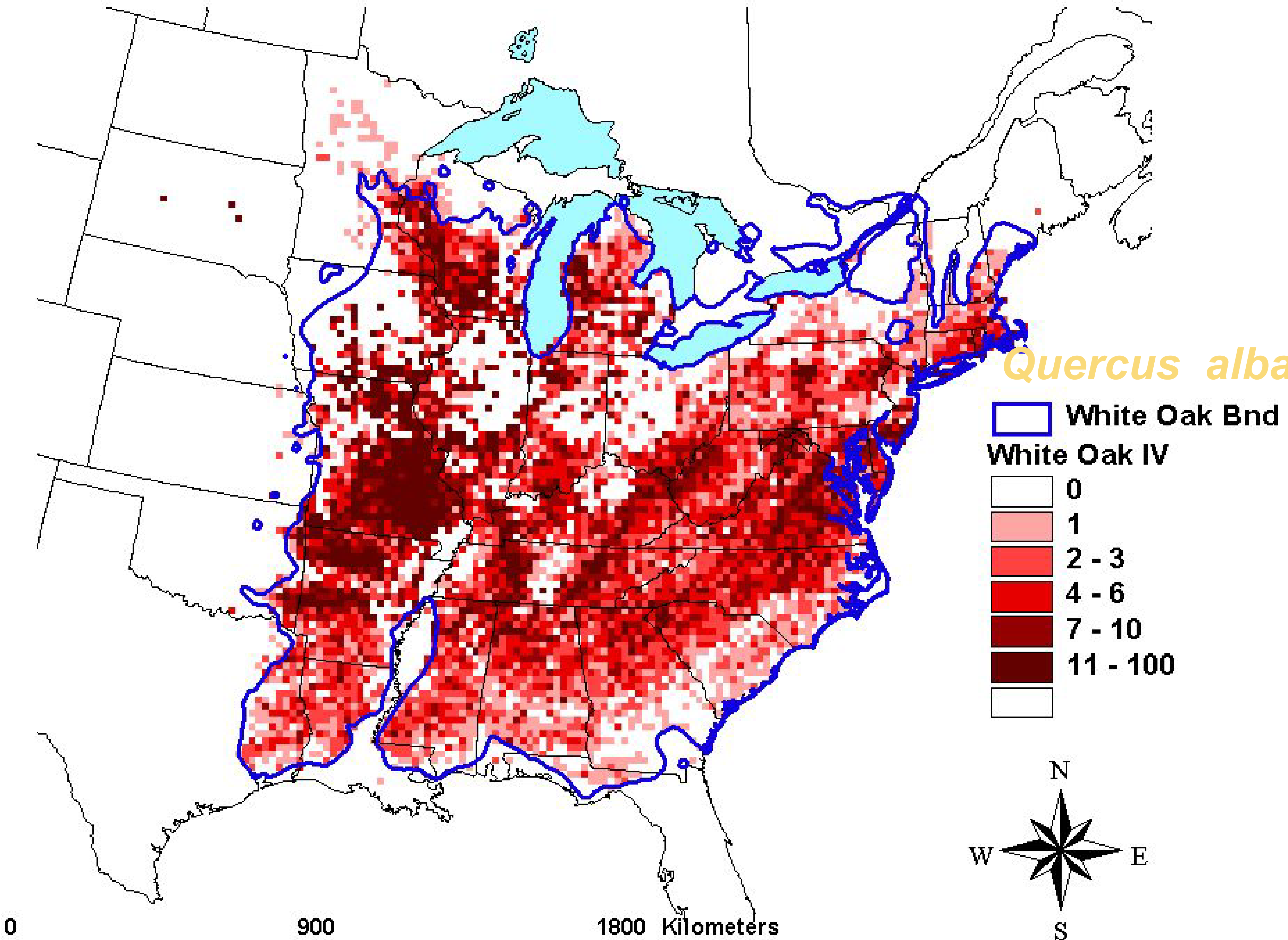
- Extract FIA plot data by State
- Calculate Importance Value (IV) for each species (basal area & no. of stems)
- Aggregate plots to 20x20 km grids (approx. 10,000 cells for eastern US)

OUTPUT

Importance Values (Abundances) (IV) for 134 tree species by 20 km cell (Range of IV: 0-100)



White Oak Importance Value and Little's Bnd



Tree species predictors

38 Predictors

- 7 Climate
- 9 Soil Classes
- 13 Soil Properties
- 5 Elevation
- 3 Land-use
- 1 Fragmentation Index

Current

GCMs, 2100
HadCM3
GFDL
PCM

IPCC
Carbon
Emission
Scenarios
A1fi (High)
B1 (Low)

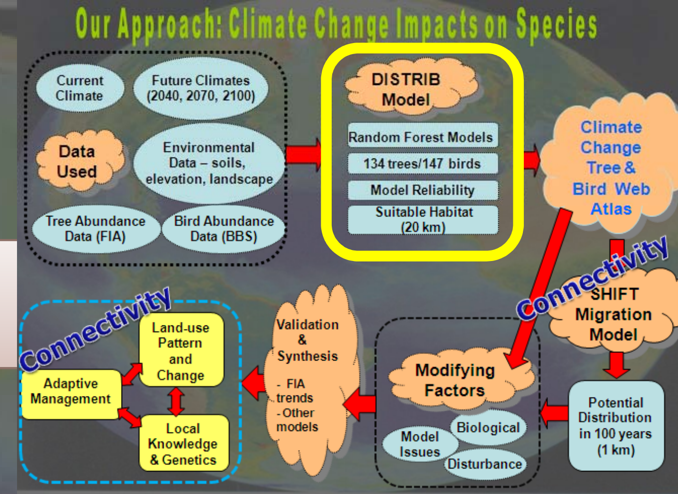
A1fi + HadCM3 (HadHi) – Most extreme

B1 + PCM (PCMLo)– Least extreme

Had+GFDL+PCM/A1fi – Ave Hi

Had+GFDL+PCM/B1 – Ave Lo

Modeling species habitats



(Importance Values)

FIA Current

Importance Values for 134 Tree Species

+

DISTRIB Tree Model

Model Predicted Current

Climate
- **Soil**
- **Elevation**
- **Land-use**
- **Landscape**

GCM Climate Swap

Model Predicted Future Suitable Habitat

HadCM3, PCM, GFDL
(Hi & Low Emissions)

Importance Maps

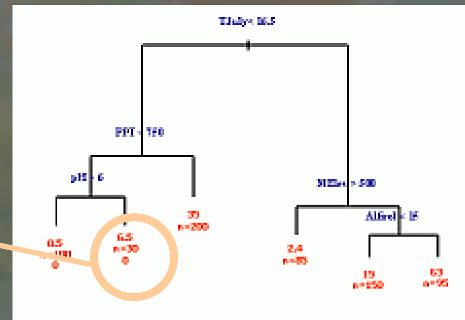
Hotspot Change Maps

Mean Center Distribution Maps

Ranked Species Lists

Tri-Model Approach

Prasad, A. M., L. R
Newer classificat
techniques: baggi
for ecological pre
Ecosystems 9:181

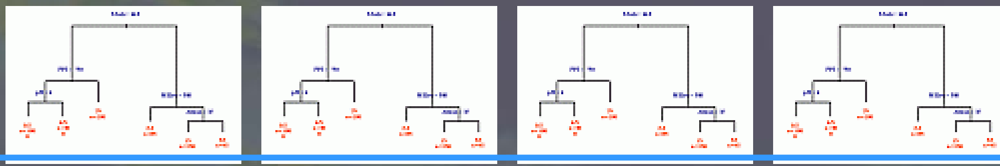


Single Decision Tree

Helps understand relationships, and map drivers

TJuly < 16.5 &
PPT < 750 &
PH <= 6

2/3 random sampling of observations for each tree



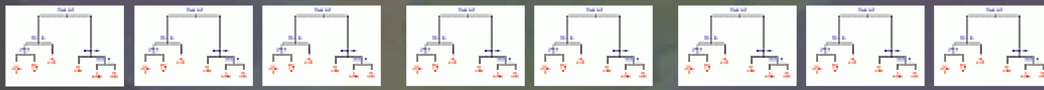
30 decision trees

Bagging Trees

use 30 decision trees to assess variability among individual tree models - a measure of **model reliability**

Model Reliability: High Medium Low

Random sampling + randomized subset of predictors for each tree



1000 decision trees

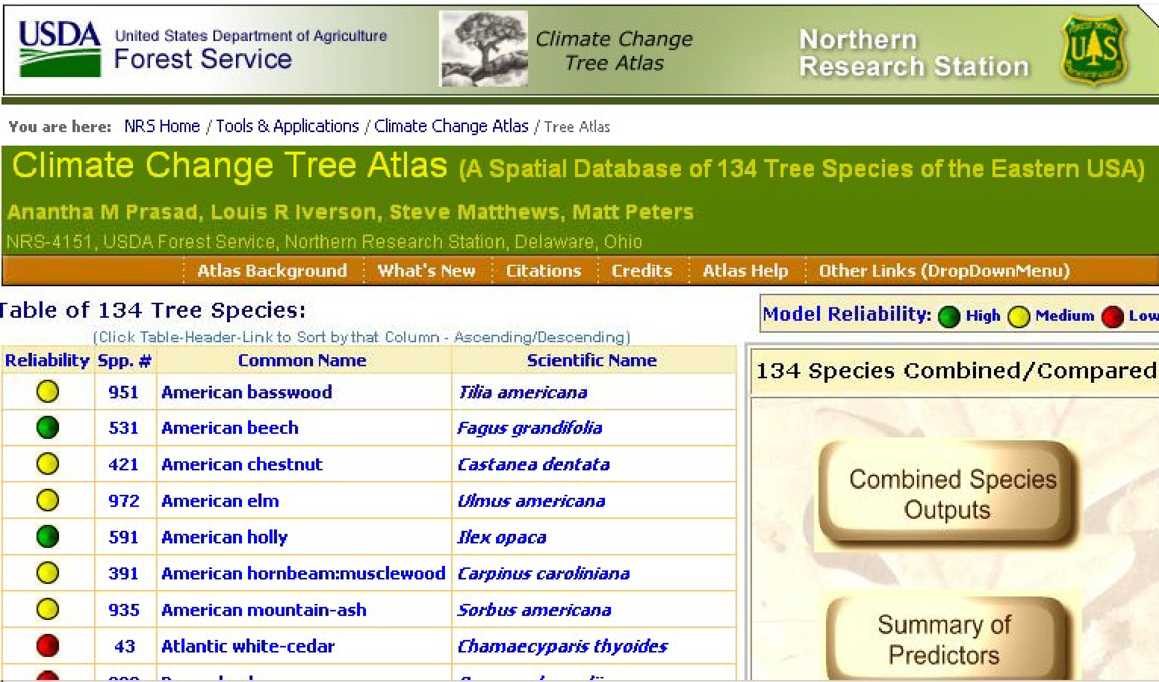
Random Forests

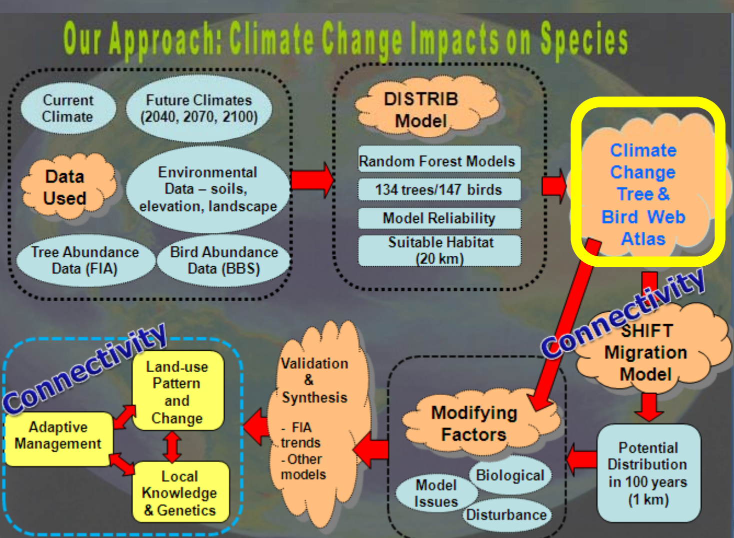
best for prediction without overfitting

Important!

- With these DISTRIB models, we are predicting potential suitable habitat by year 2100. We are NOT predicting where the species will be at that time, as great lag times are involved in tree species migrations.
- We attempt to get at the potential movements over the next 100 yrs with the SHIFT model.

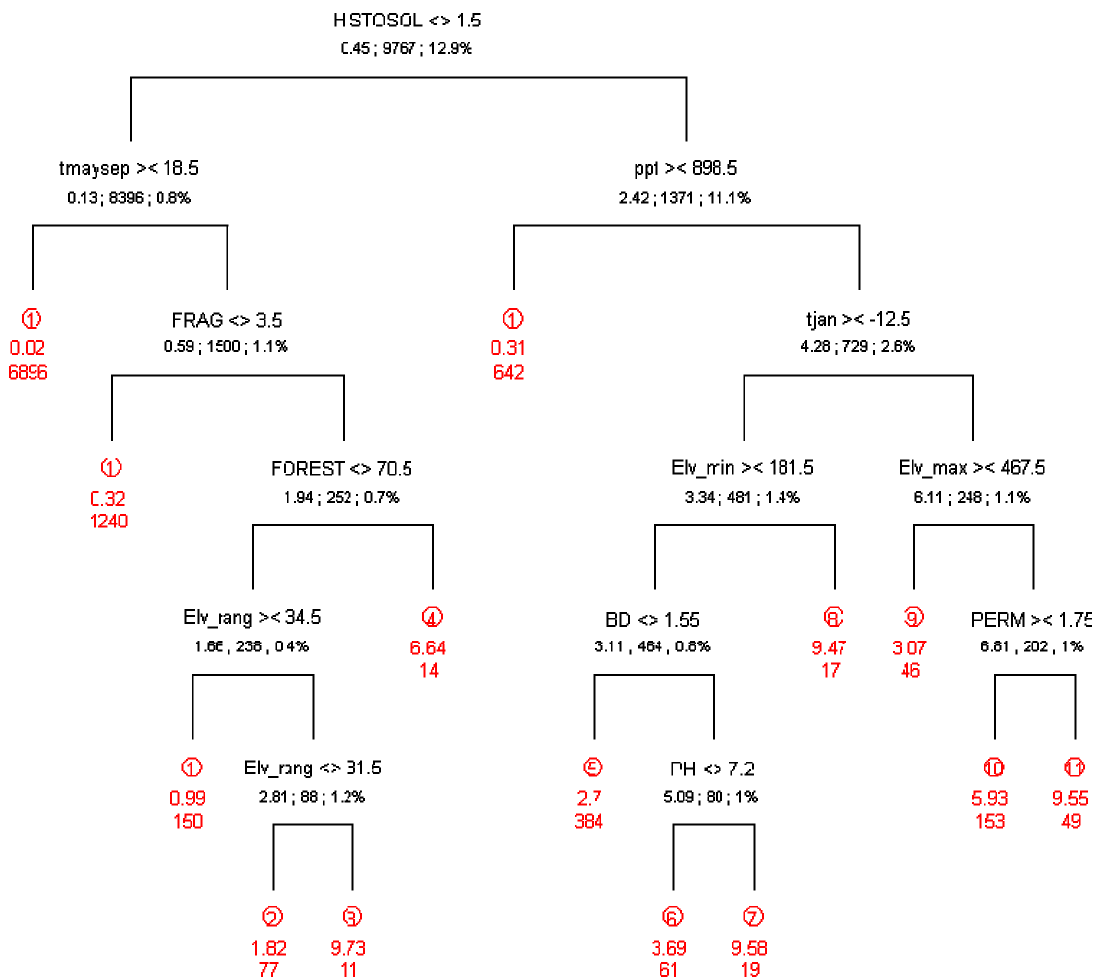
Climate Change Tree Atlas



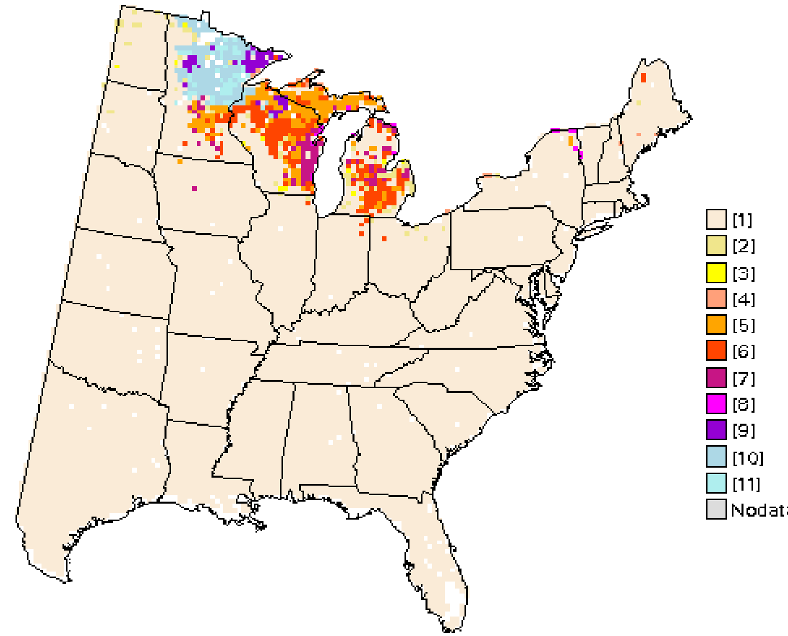


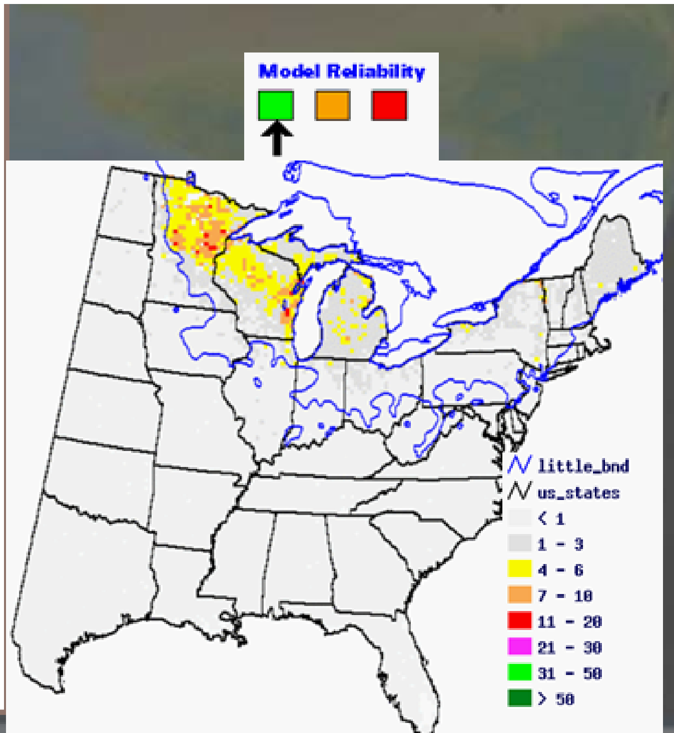
http://www.nrs.fs.fed.us/atlas

Black Ash

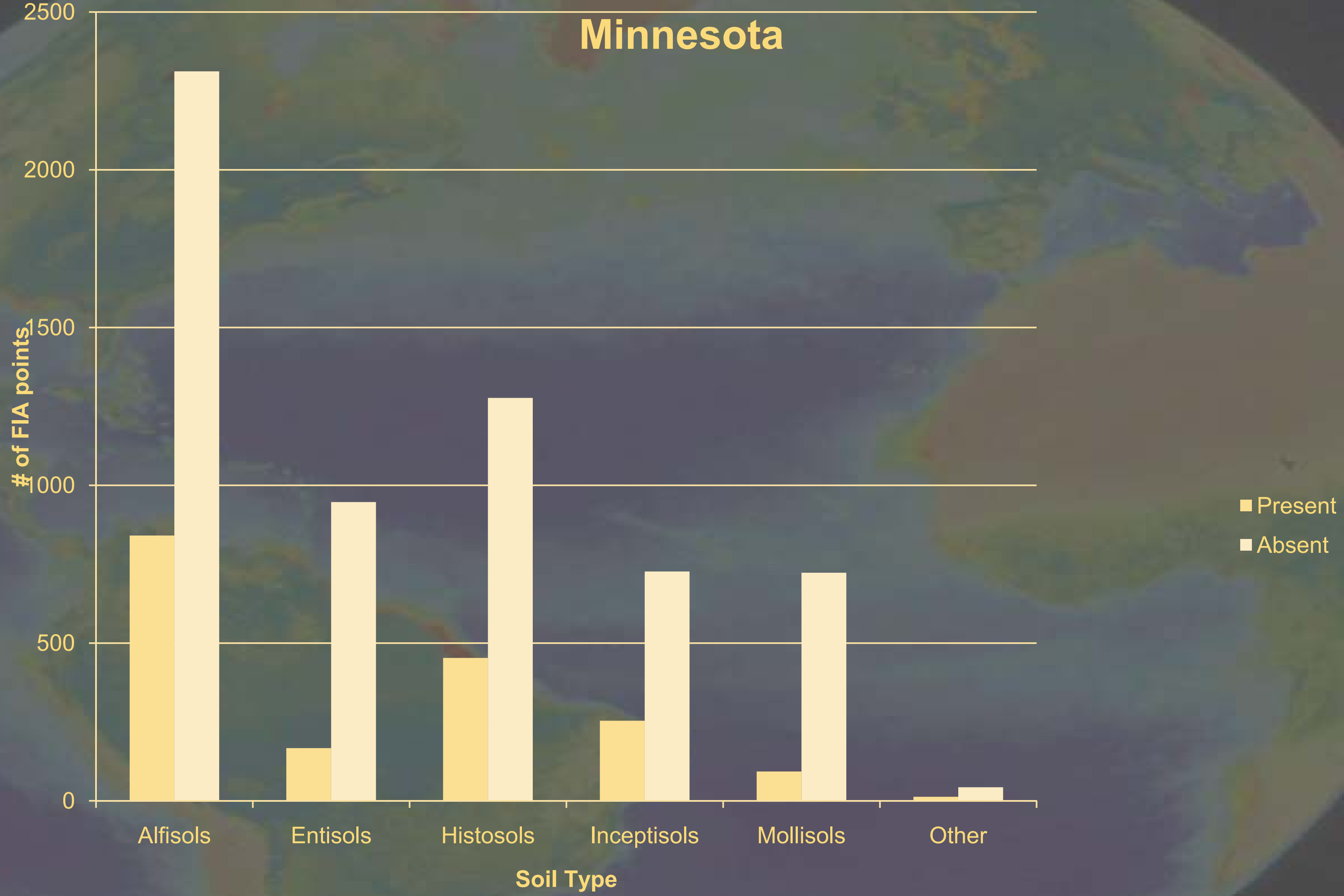


Total deviance explained = 36.1 %

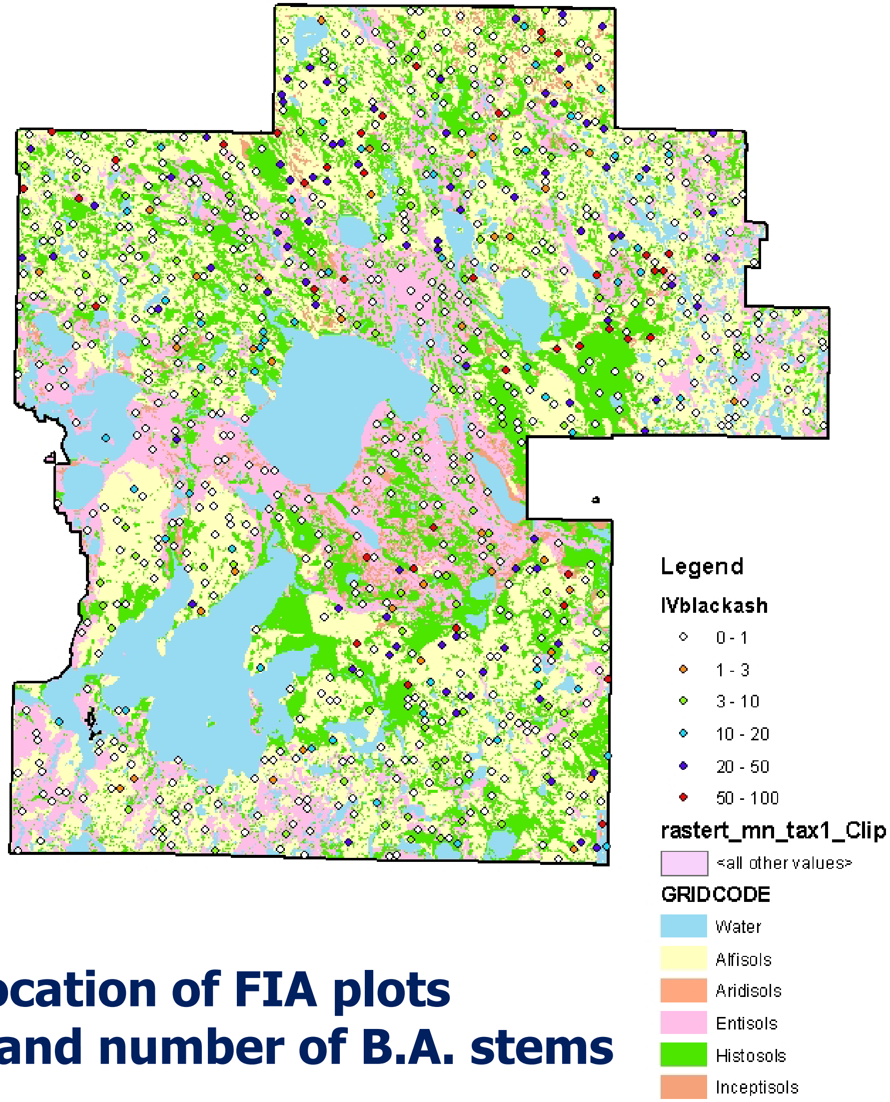




Number of MN FIA Plots with Black Ash Present

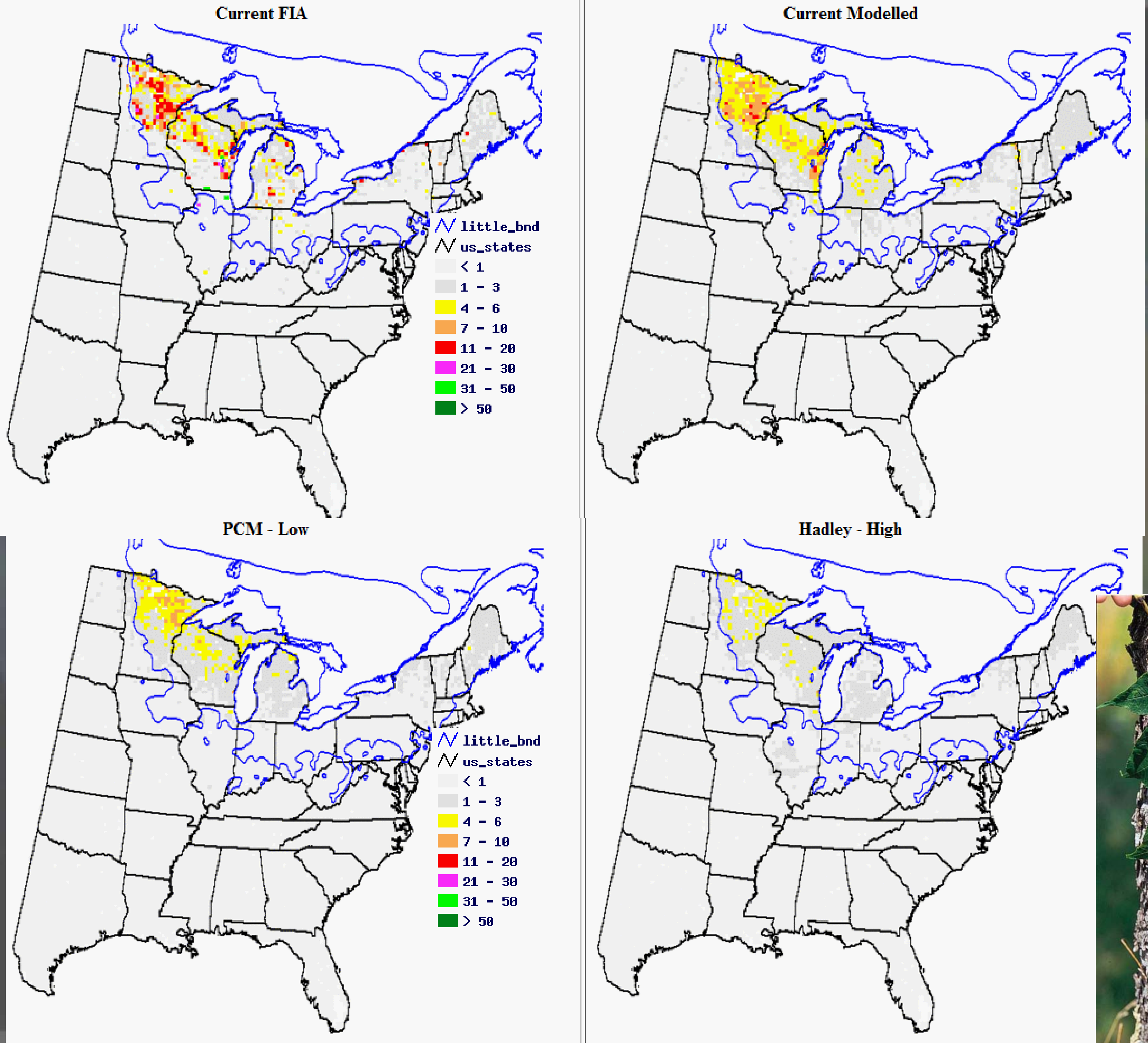


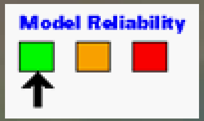
Chippewa National Forest



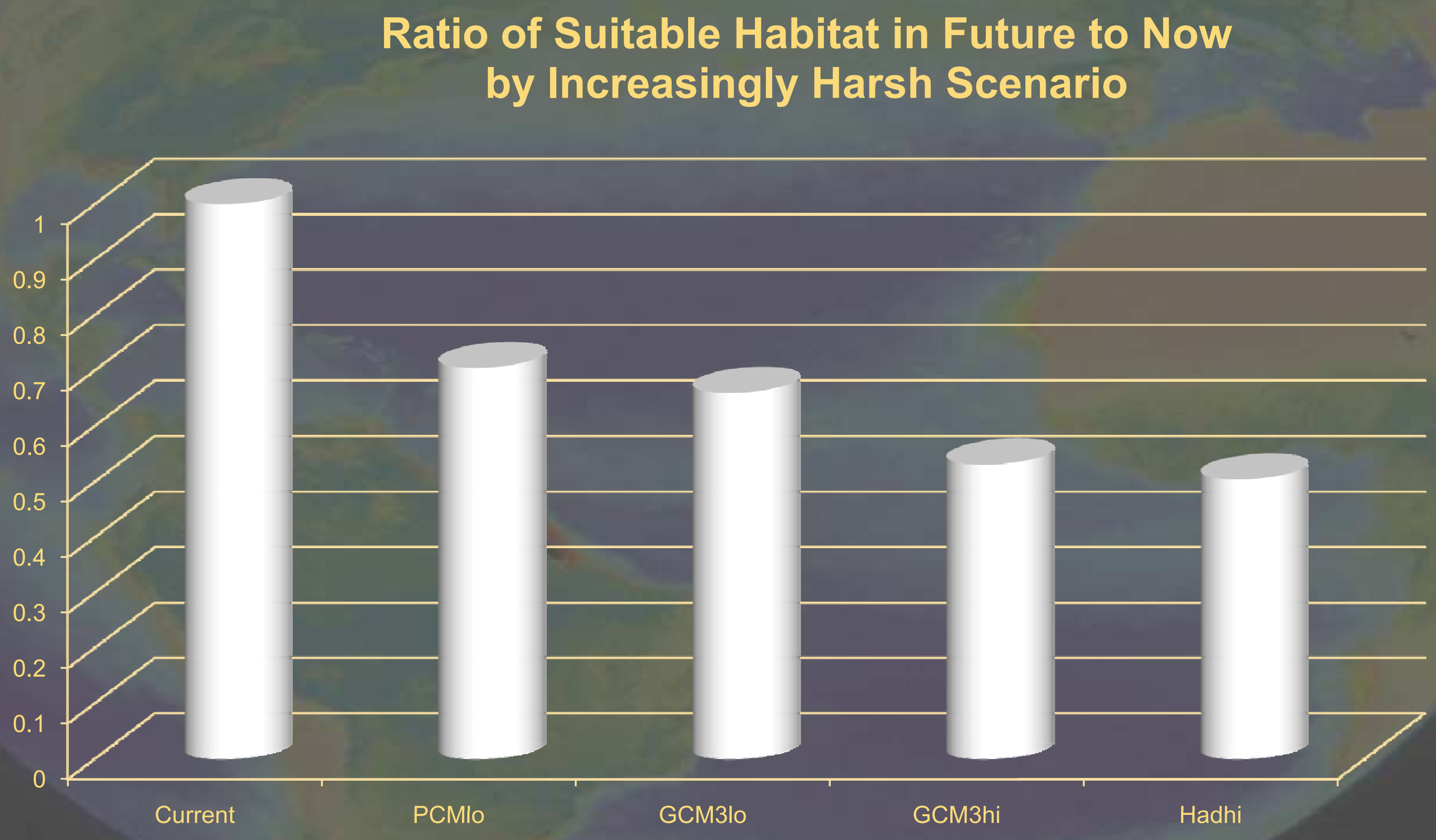
Location of FIA plots and number of B.A. stems

Black Ash

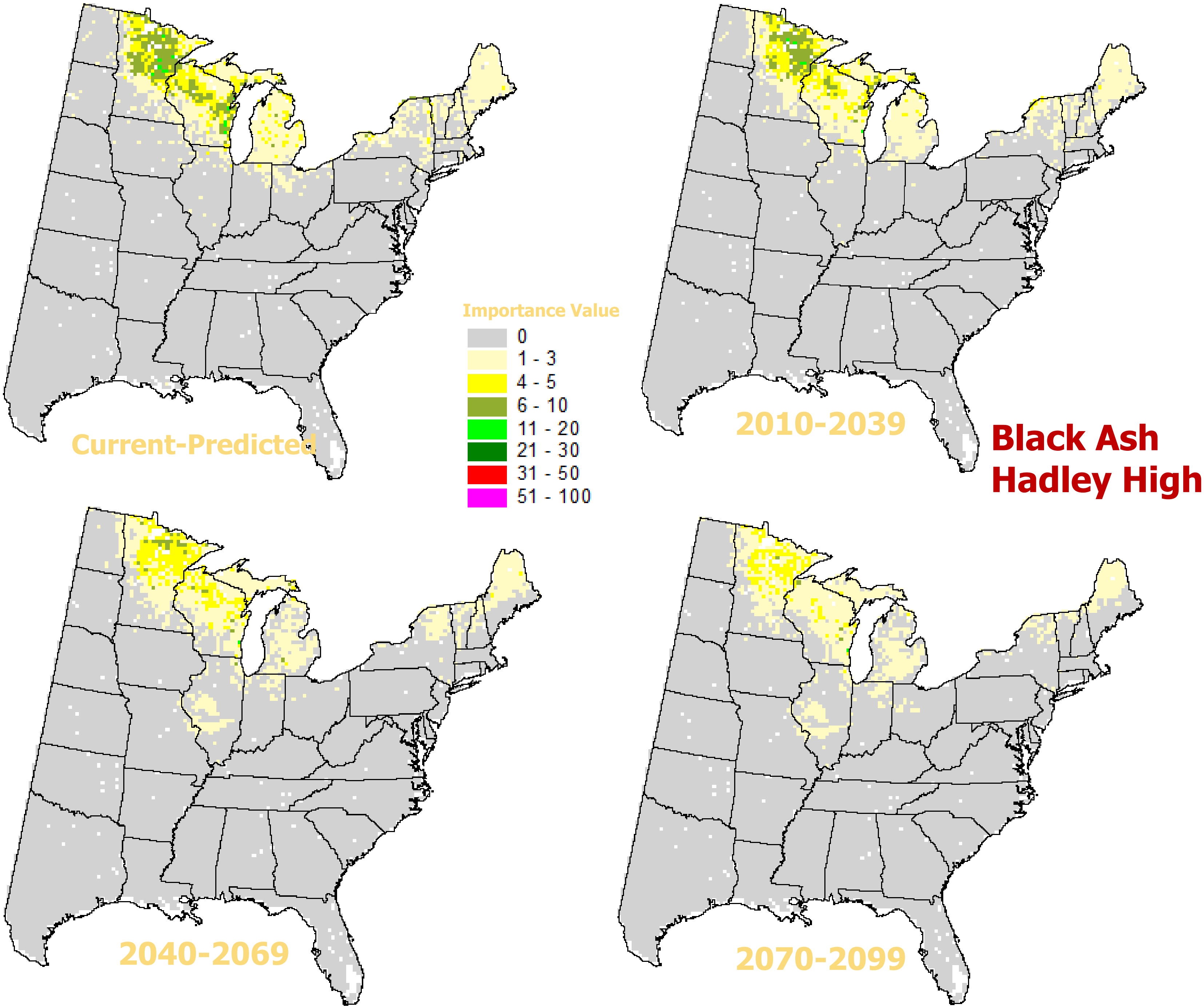

Current FIA
Current Modelled
PCM - Low
Hadley - High
little_bnd
us_states
< 1
1 - 3
4 - 6
7 - 10
11 - 20
21 - 30
31 - 50
> 50


Model Reliability

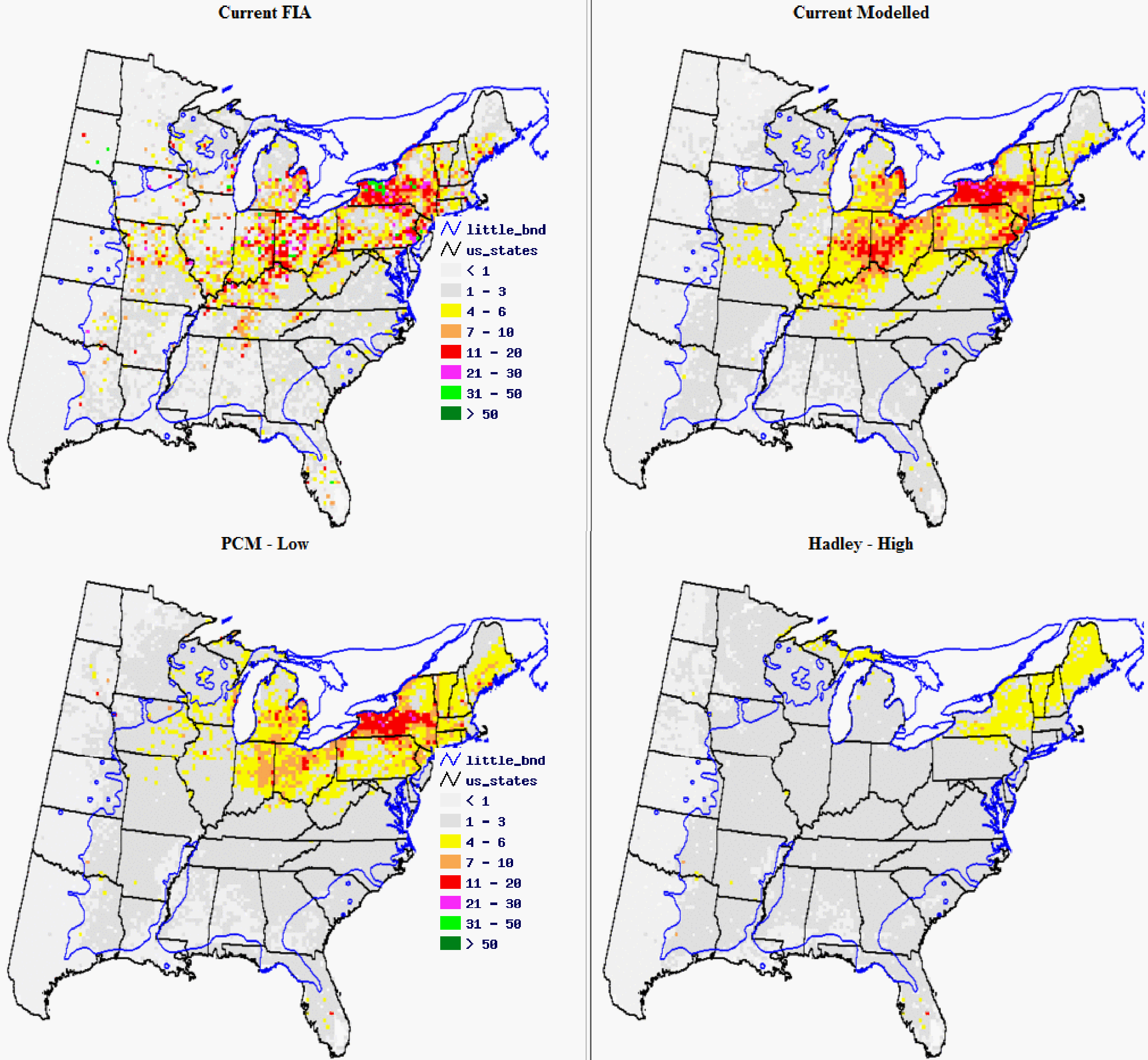
Black ash habitat would decline by 2100

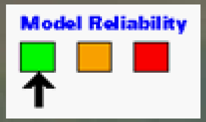


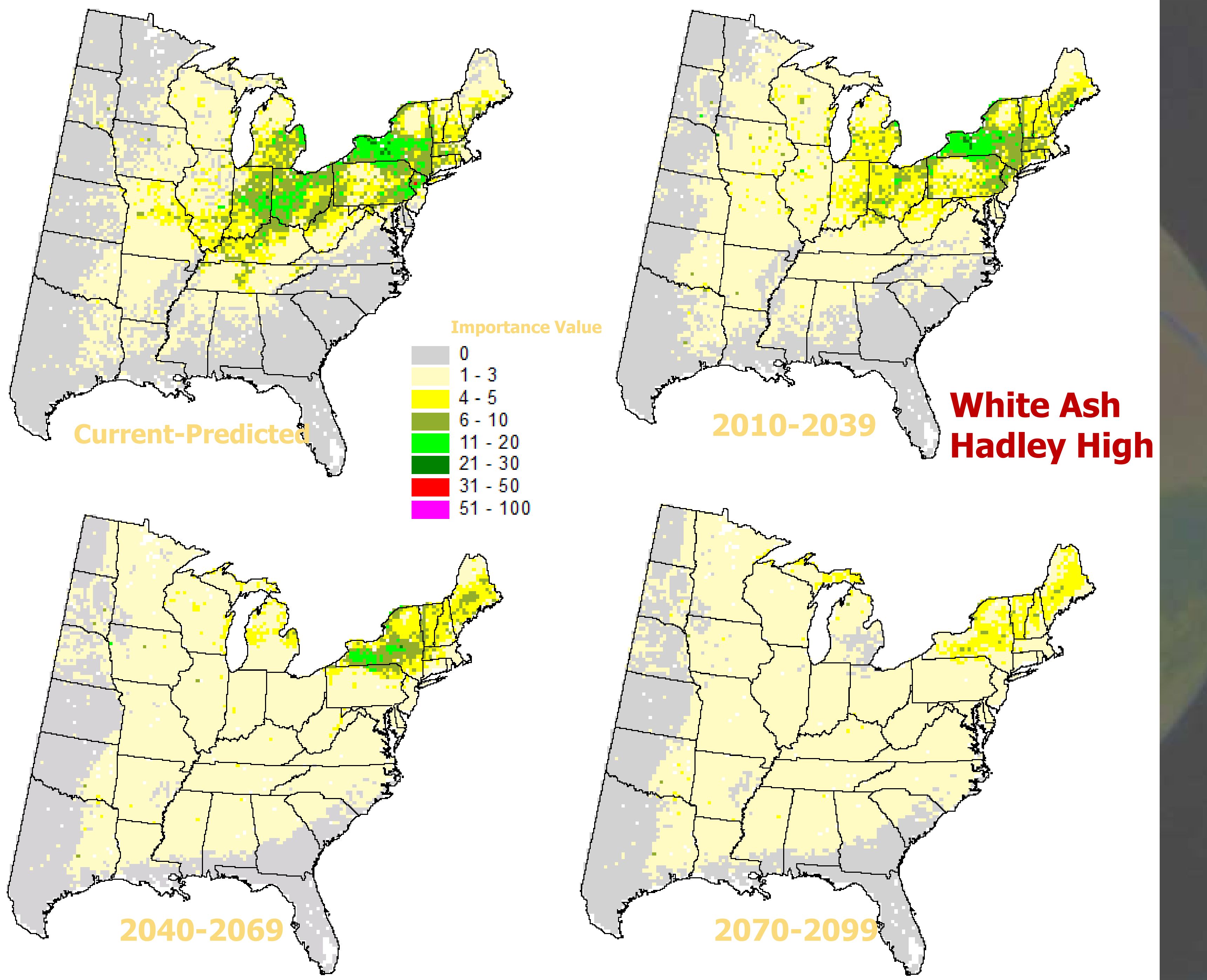
Black Ash Hadley High



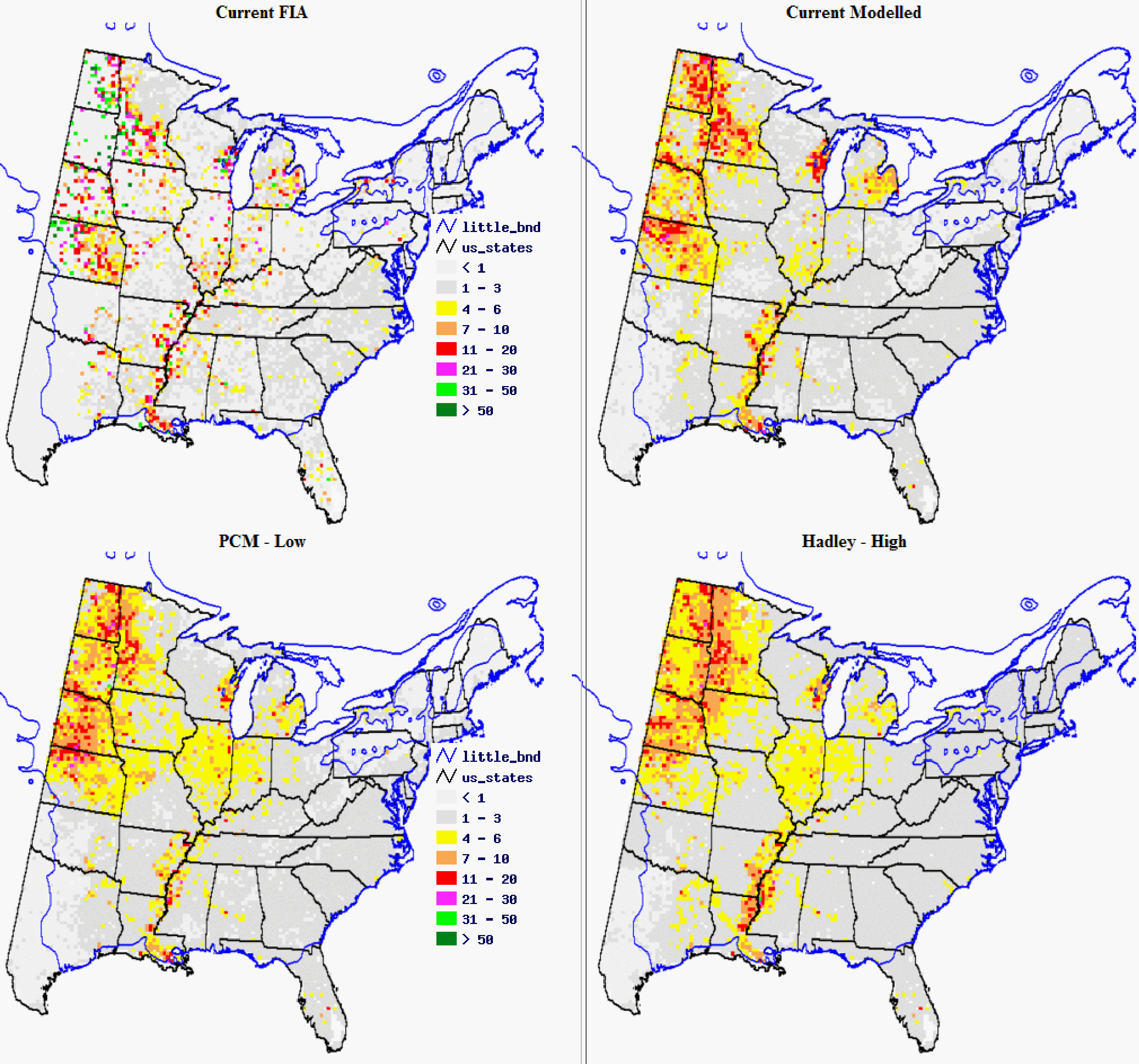
White Ash


Current FIA
Current Modelled
PCM - Low
Hadley - High
little_bnd
us_states
< 1
1 - 3
4 - 6
7 - 10
11 - 20
21 - 30
31 - 50
> 50


Model Reliability


White Ash
Hadley High
Current-Predicted
2010-2039
2040-2069
2070-2099
Importance Value
0
1 - 3
4 - 5
6 - 10
11 - 20
21 - 30
31 - 50
51 - 100

Green Ash



Current FIA
Current Modelled
PCM - Low
Hadley - High
little_bnd
us_states
< 1
1 - 3
4 - 6
7 - 10
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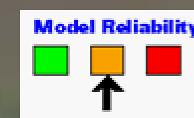
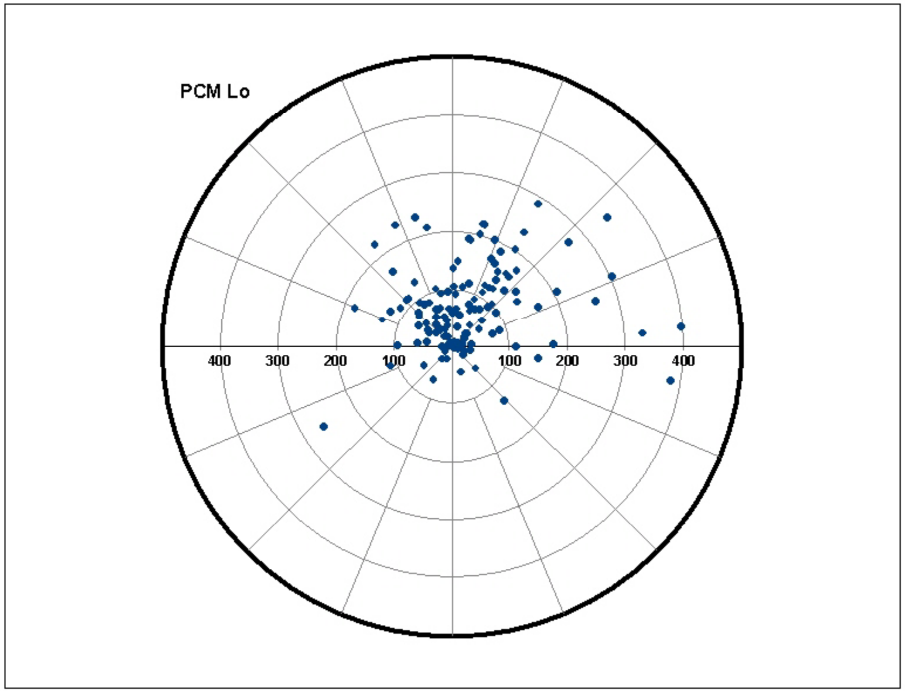
21 - 30
31 - 50
> 50



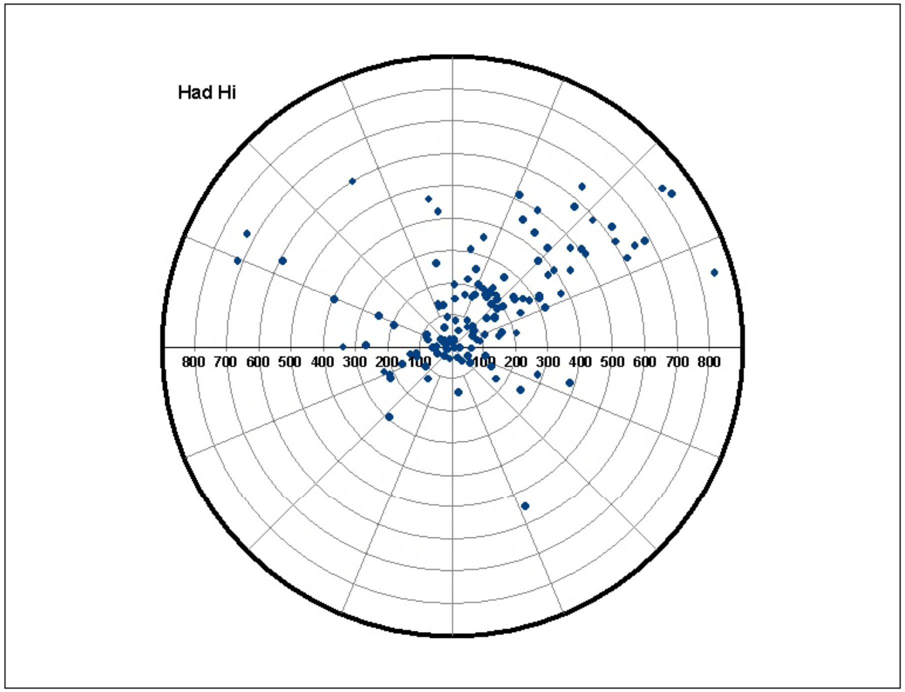
Model Reliability

Mean Center Potential Movement



Two points:

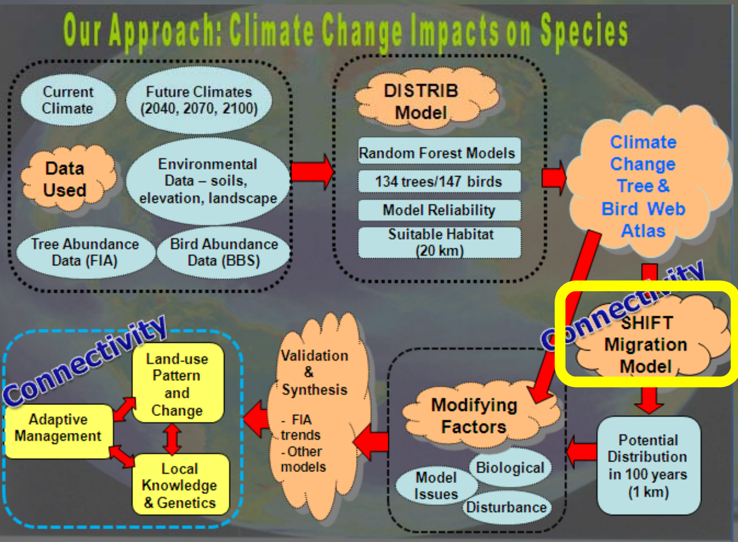
1. **Emission levels make big difference**
2. **Species will change individually**

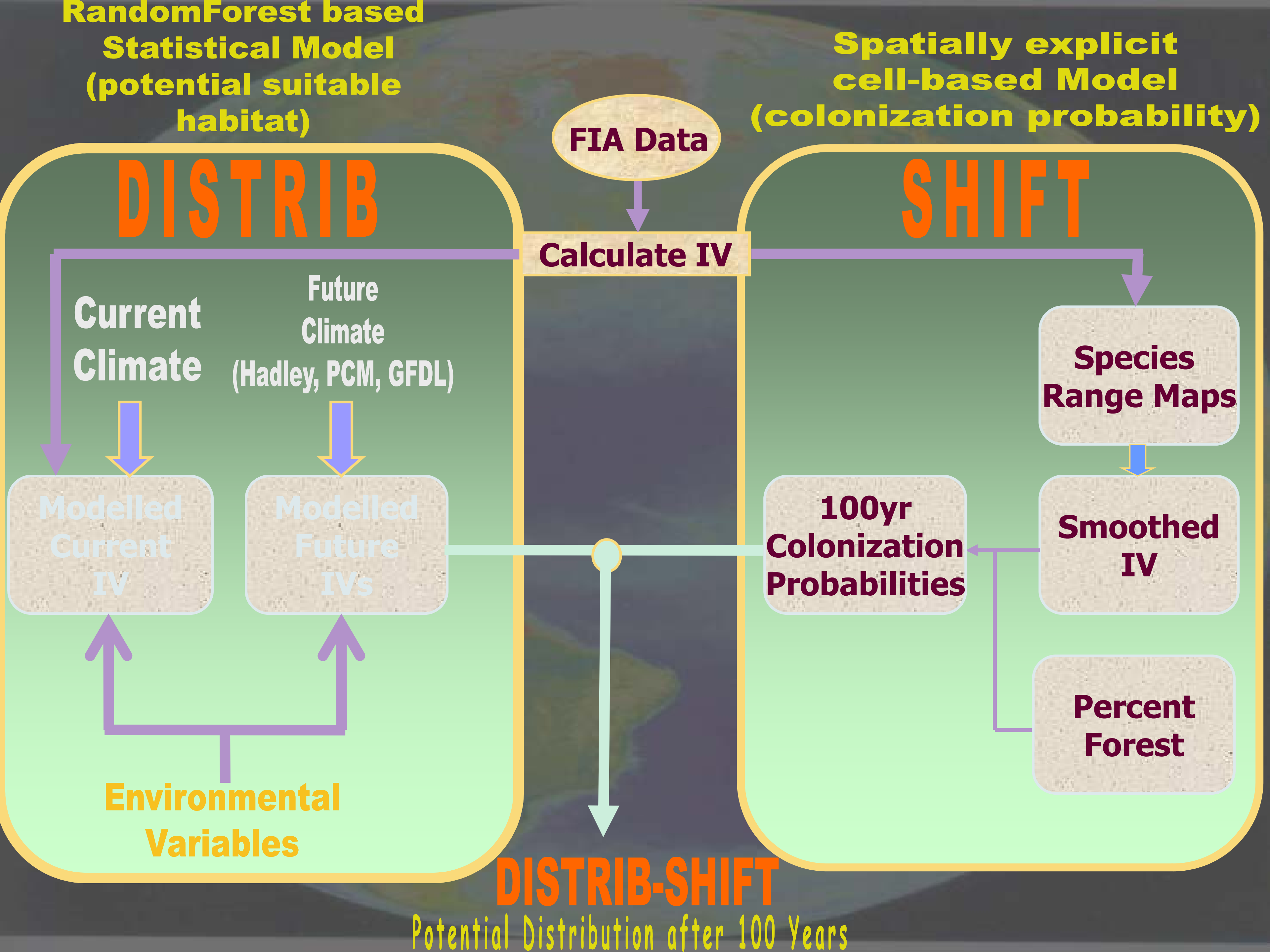


Direction and distance (km) movement

Lessons Learned

Separate the discussion of potential changes in suitable habitat from that of potential species range changes within a certain time frame.

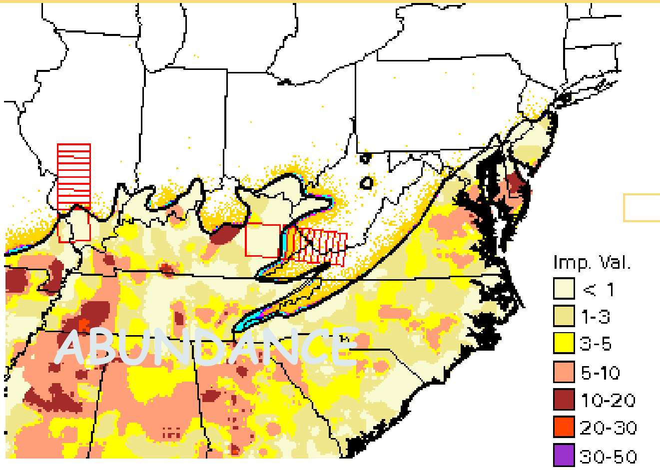




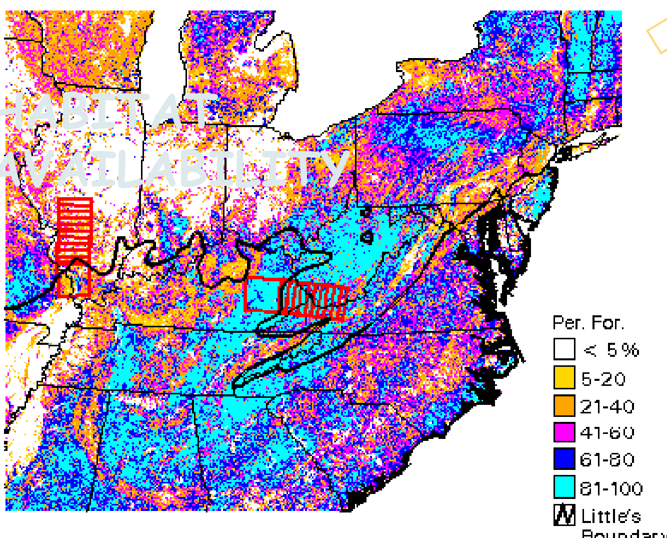
RandomForest based Statistical Model (potential suitable habitat)
Spatially explicit cell-based Model (colonization probability)
FIA Data
DISTRIB
SHIFT
Calculate IV
Current Climate
Future Climate (Hadley, PCM, GFDL)
Species Range Maps
Modelled Current IV
Modelled Future IVs
100yr Colonization Probabilities
Smoothed IV
Percent Forest
Environmental Variables
DISTRIB-SHIFT
Potential Distribution after 100 Years

How much of the new suitable habitat might get colonized in 100 years?

Quercus falcata var. falcata

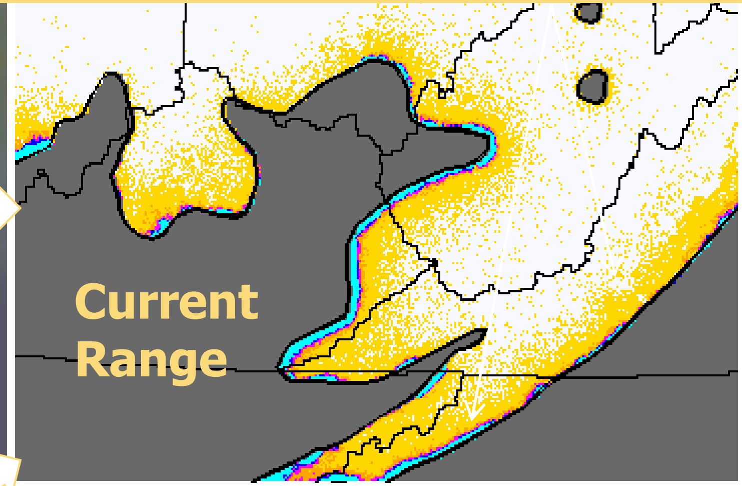


SHIFT Transects



Forest Density Transects

Probability of colonization, 0-100%, 100 yrs



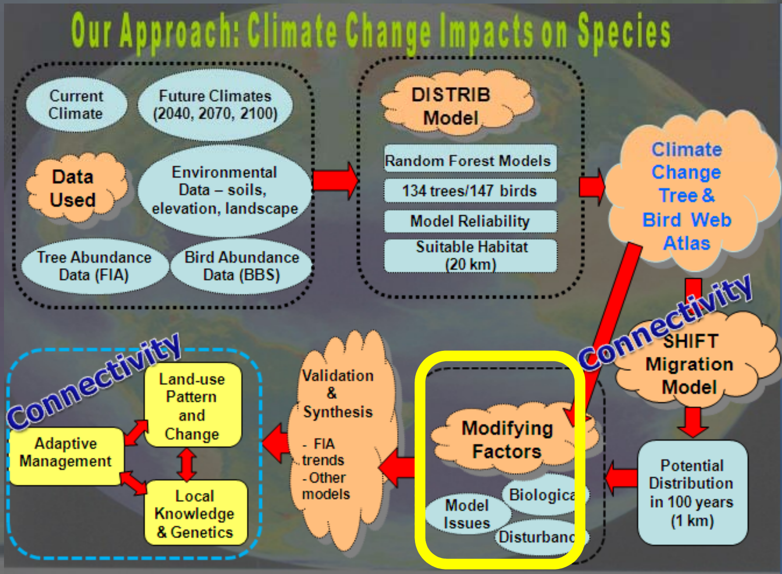
Zoomed SHIFT

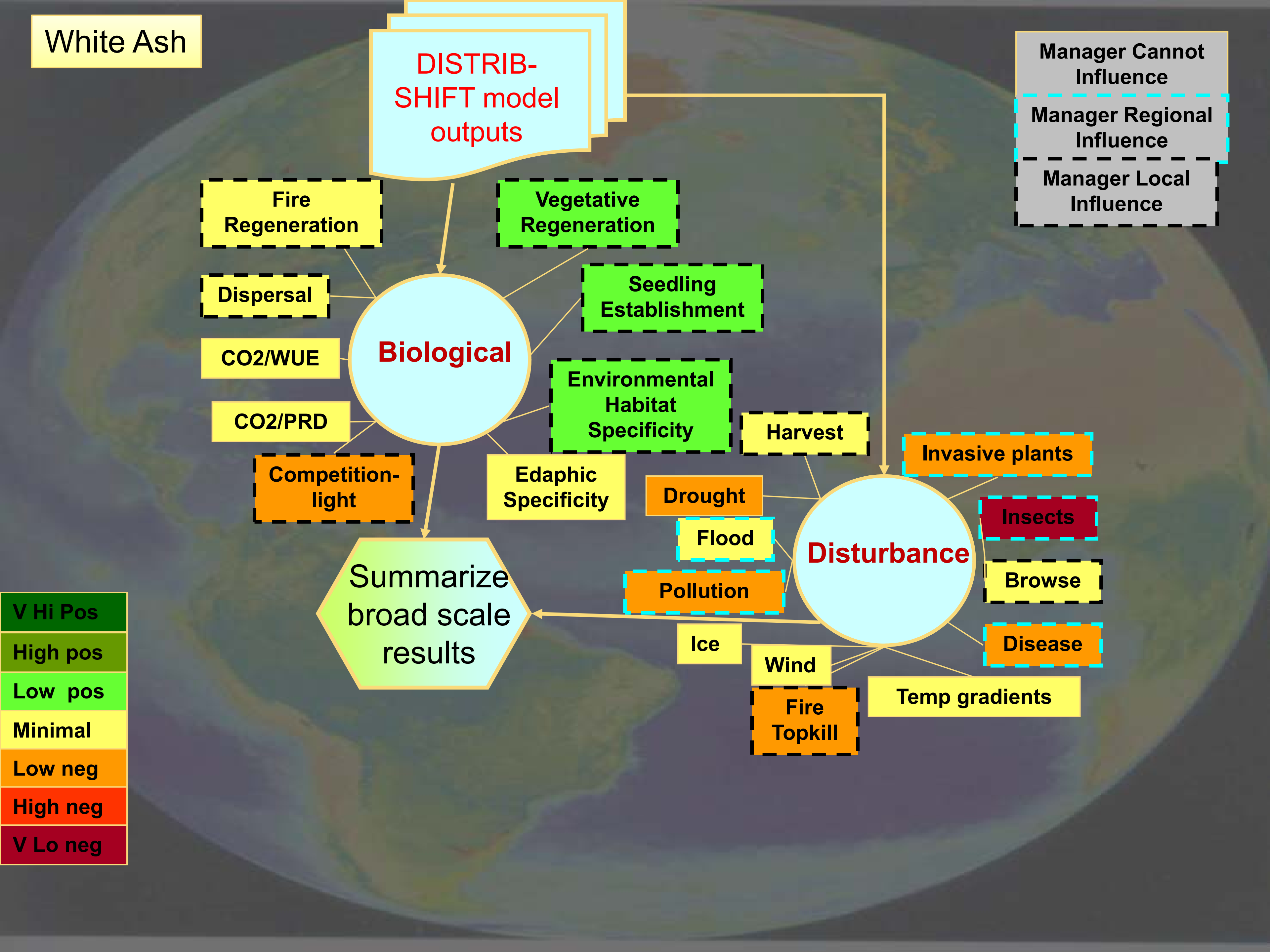
- For 5 species, less than 15% of new habitat would have much chance of getting colonized
- Large lag effect – suitable habitat changes much faster than species can migrate

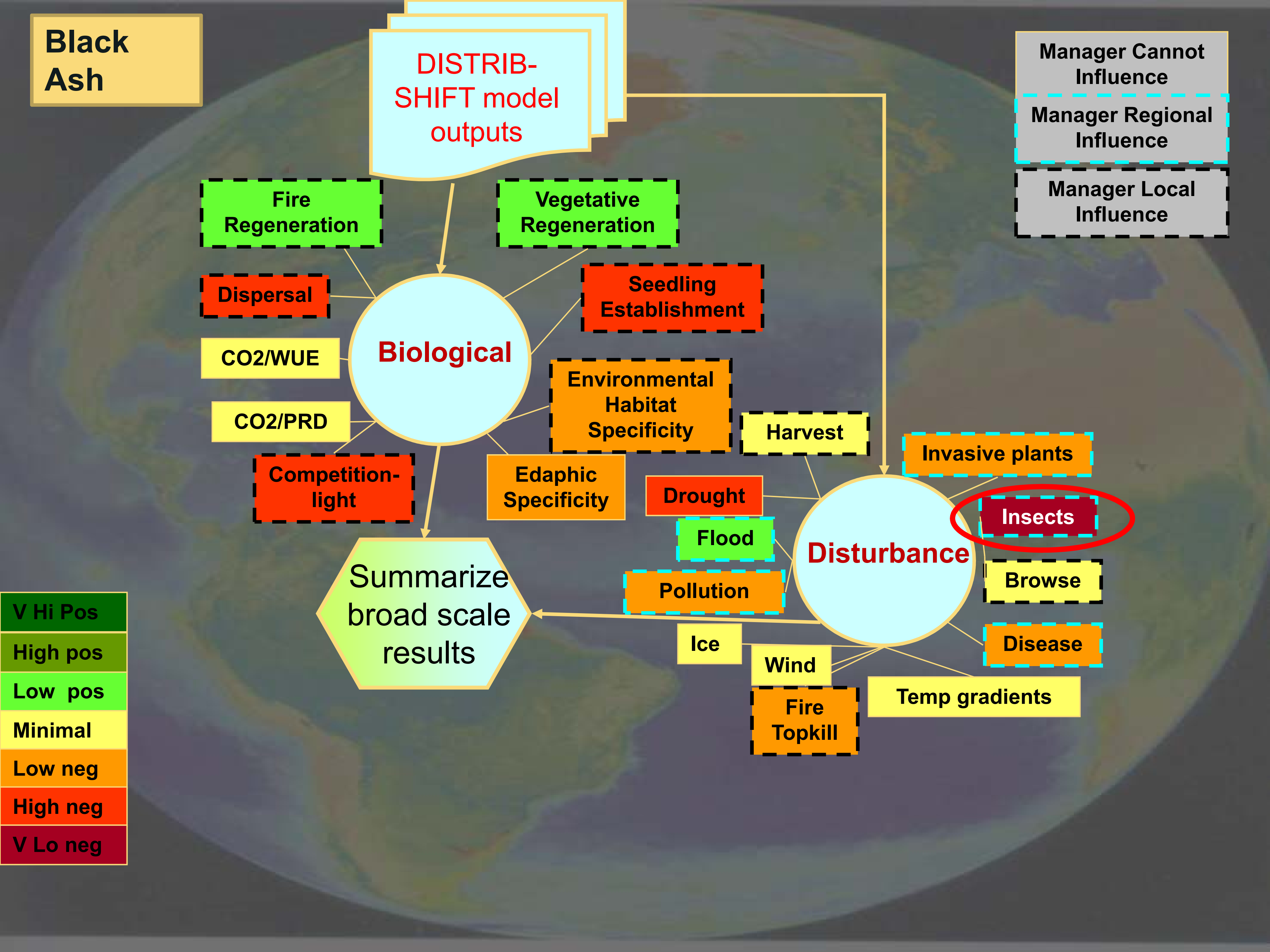
Lessons Learned

Consider variations in disturbance, biology, and model issues on each modeled species.

- No model, statistical or otherwise, can include all the biological or disturbance factors that may influence a species' response to climate change
- Need a method to incorporate other influences – modifying factors
- Glean literature and generate a scoring system to rate 21 factors




White Ash
DISTRIB-SHIFT model outputs
Manager Cannot Influence
Manager Regional Influence
Manager Local Influence
Fire Regeneration
Vegetative Regeneration
Dispersal
Seedling Establishment
CO2/WUE
Biological
Environmental Habitat Specificity
CO2/PRD
Harvest
Invasive plants
Competition-light
Edaphic Specificity
Drought
Insects
Flood
Disturbance
Summarize broad scale results
Browse
Pollution
V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg
Ice
Disease
Wind
Fire Topkill
Temp gradients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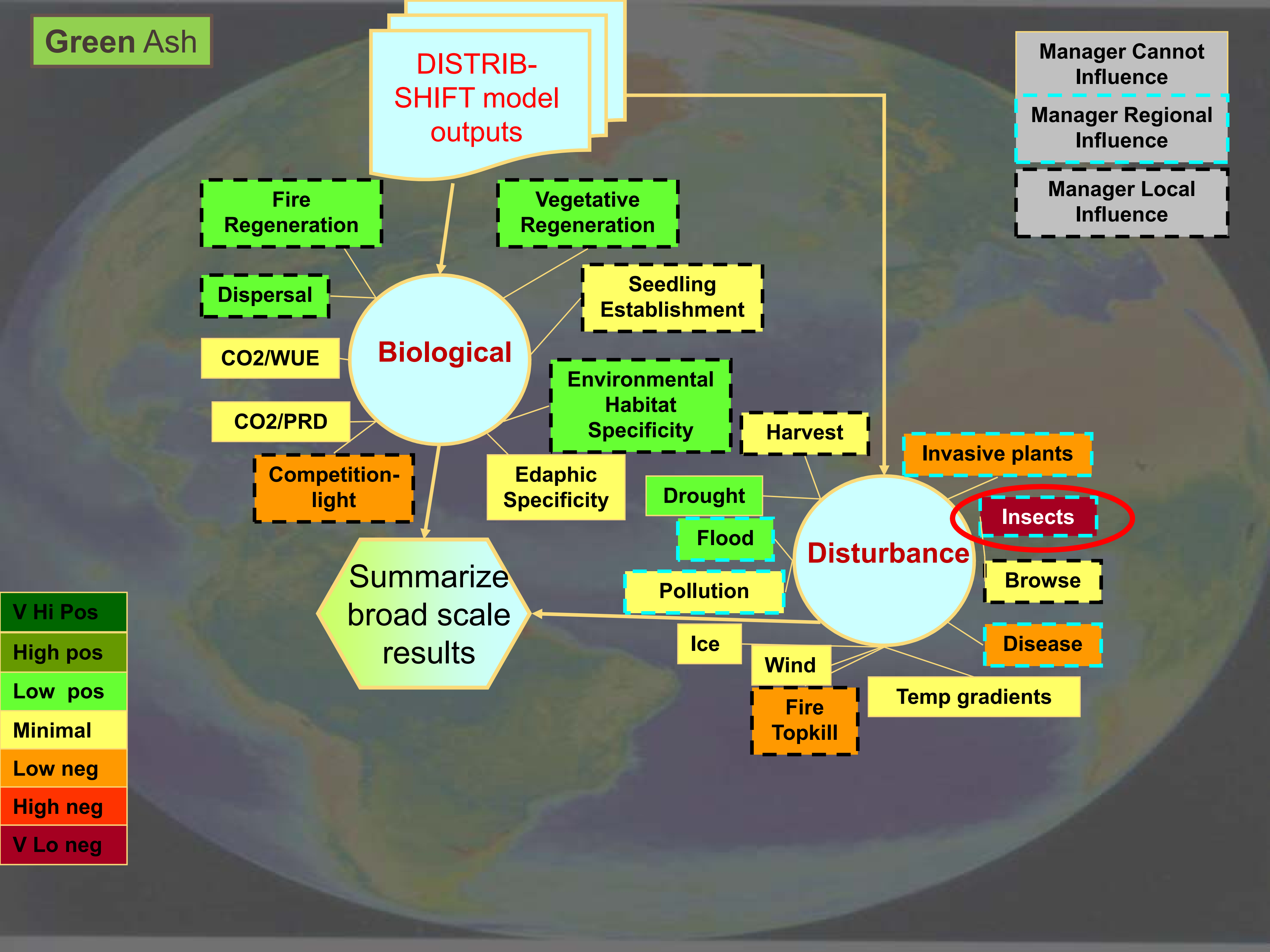
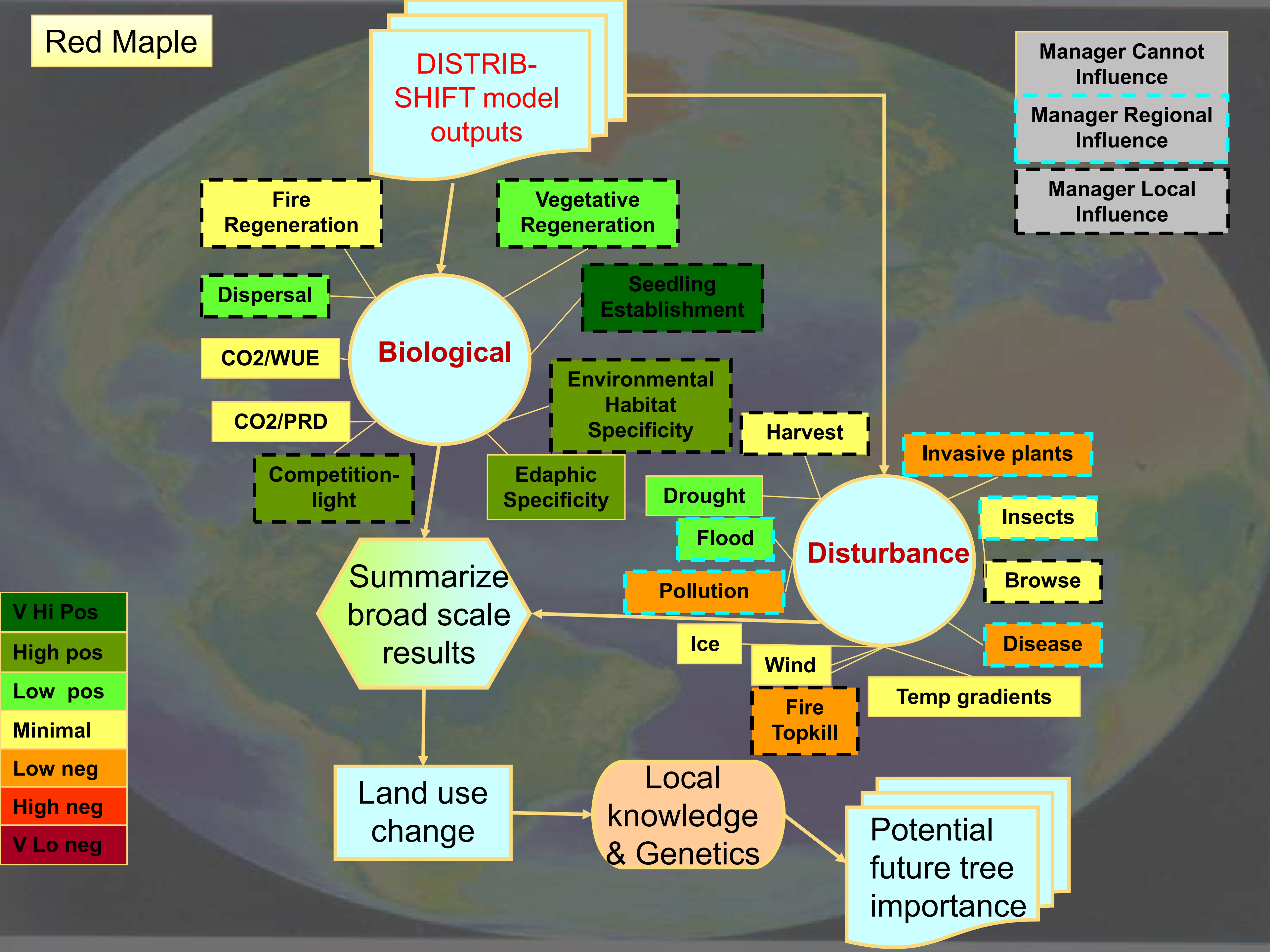
Environmental Habitat Specificity
Competition-light
Edaphic Specificity
Harvest
Invasive plants
Drought
Insects
Flood
Disturbance
Browse
Pollution
Summarize broad scale results
Ice
Disease
Wind
Fire Topkill
Temp gradients
V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg


Green Ash
DISTRIB-SHIFT model outputs
Manager Cannot Influence
Manager Regional Influence
Manager Local Influence
Fire Regeneration
Vegetative Regeneration
Dispersal
Seedling Establishment
CO2/WUE
Biological
CO2/PRD
Environmental Habitat Specificity
Competition-light
Edaphic Specificity
Harvest
Invasive plants
Drought
Insects
Flood
Disturbance
Pollution
Browse
Summarize broad scale results
Ice
Disease
Wind
Temp gradients
Fire Topkill
V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg



Red Maple
DISTRIB-SHIFT model outputs
Manager Cannot Influence
Manager Regional Influence
Manager Local Influence
Fire Regeneration
Vegetative Regeneration
Dispersal
Seedling Establishment
CO2/WUE
Biological
CO2/PRD
Environmental Habitat Specificity
Competition-light
Edaphic Specificity
Harvest
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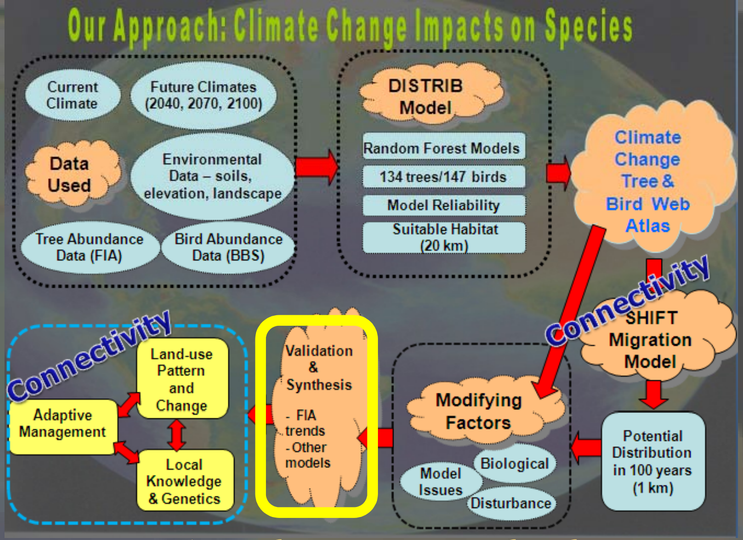
Ice
Disease
Wind
Temp gradients
Fire Topkill
Summarize broad scale results
V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg
Land use change
Local knowledge & Genetics
Potential future tree importance

Lessons Learned



Search for data to support (or not) the models

- Convergence of multiple models
  - e.g., Nielson et al. (MAPPS, MC1)
  - Mladenoff et al. (LANDIS-II)
- Documentations of species changes
  - e.g., northward or elevation expansions,
  - changes in forest types
- Other surrogate ways to determine possible trends
  - E.g., Woodall et al. (FIA data)

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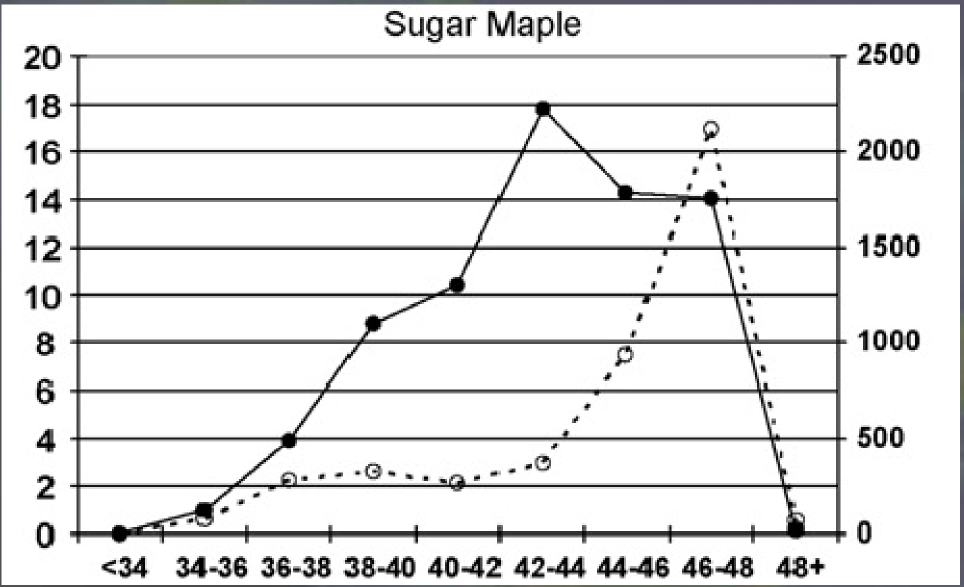
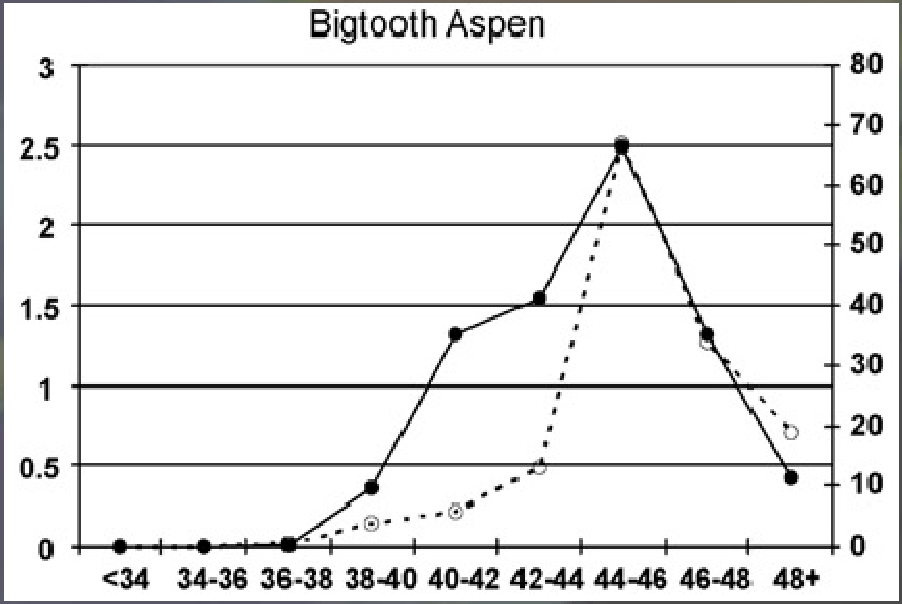
journal homepage: www.elsevier.com/locate/foreco

An indicator of tree migration in forests of the eastern United States

C.W. Woodall [a,*], C.M. Oswalt [b], J.A. Westfall [c], C.H. Perry [a], M.D. Nelson [a], A.O. Finley [d]

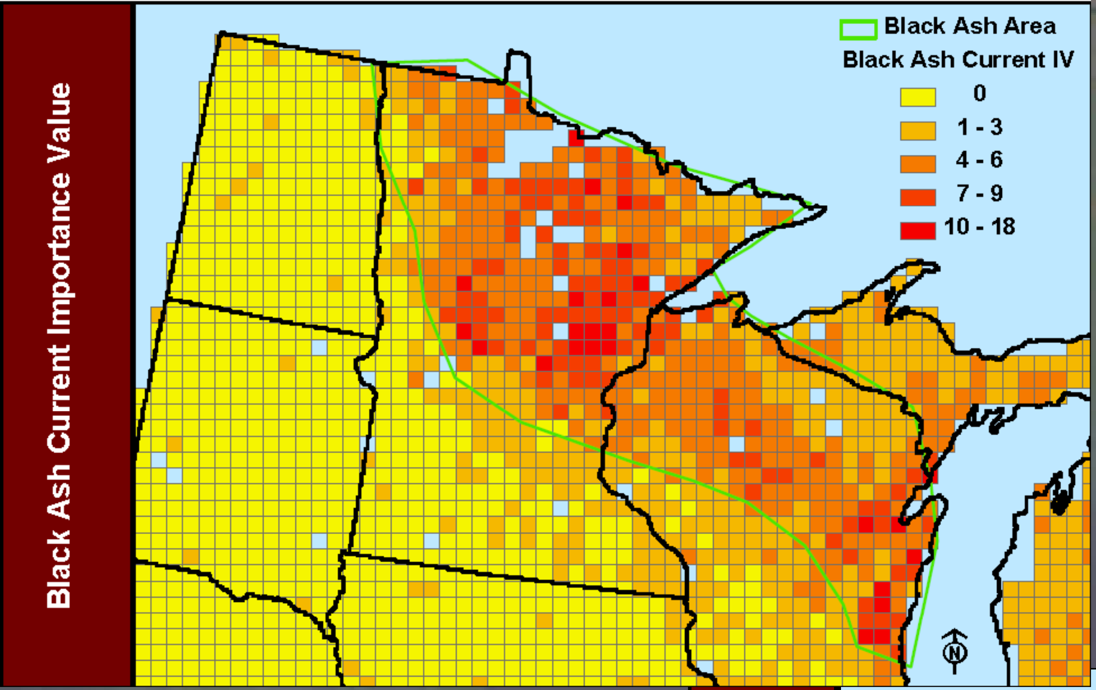




.13º North***

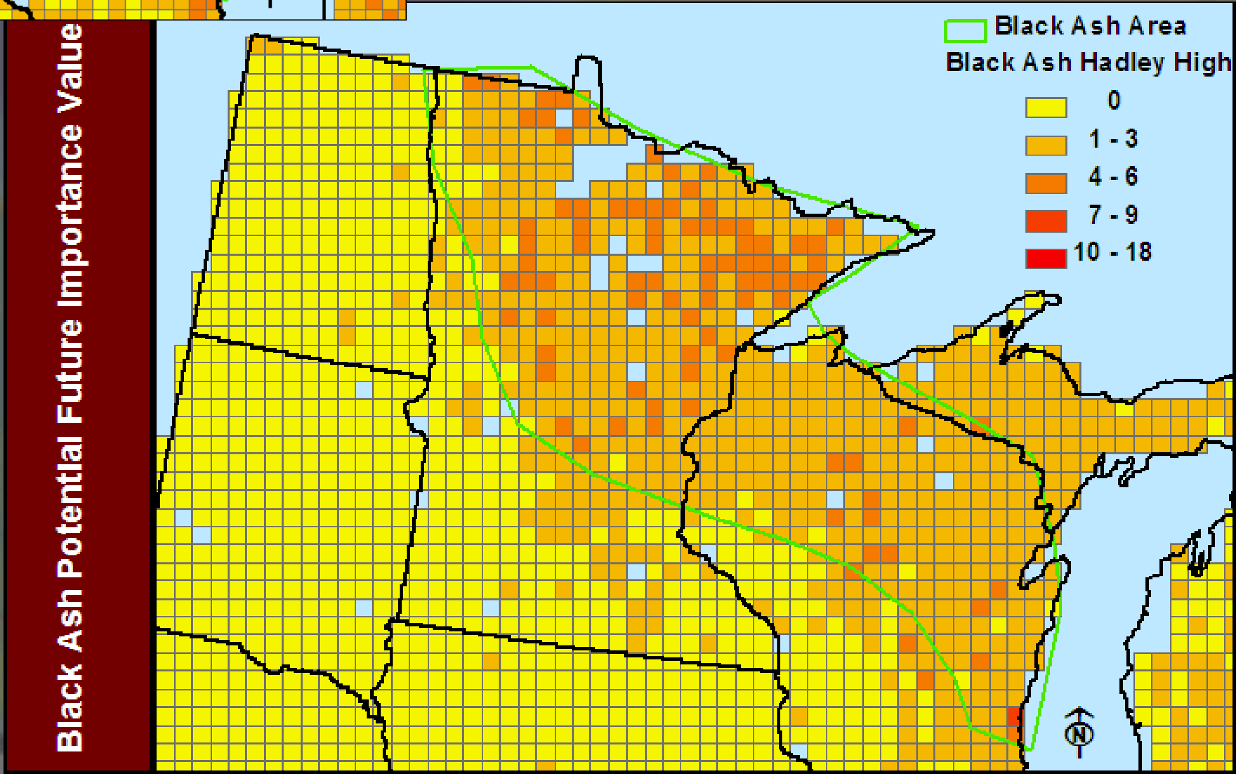
.46º North ***

37 of 40 species have general tendencies in agreement with our models

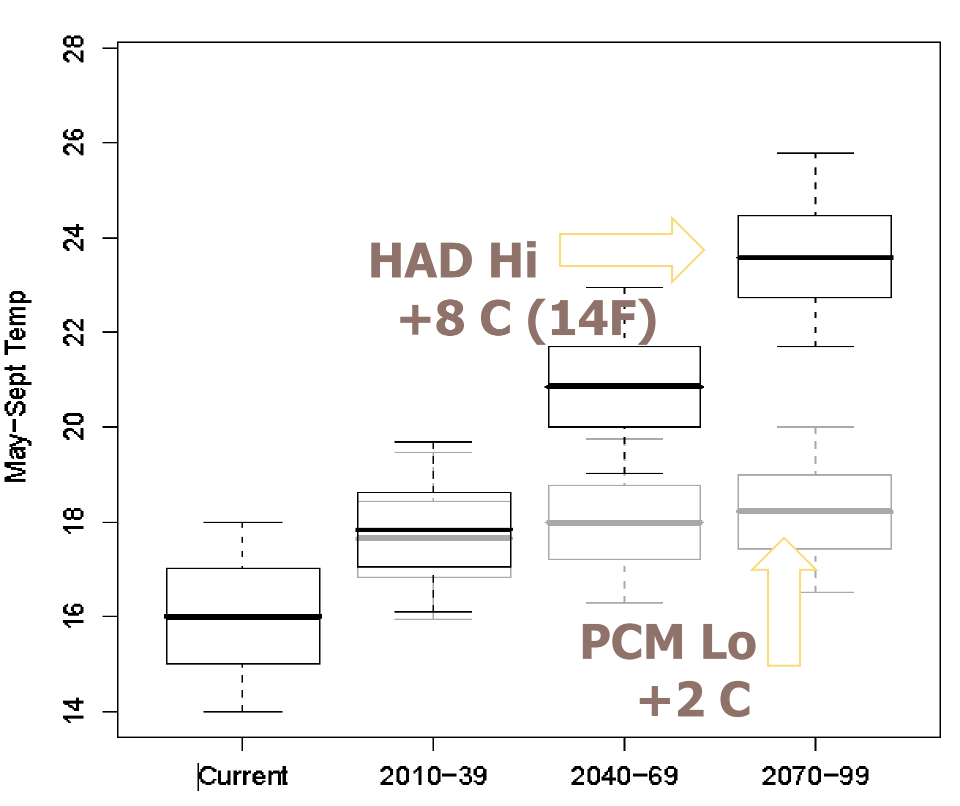


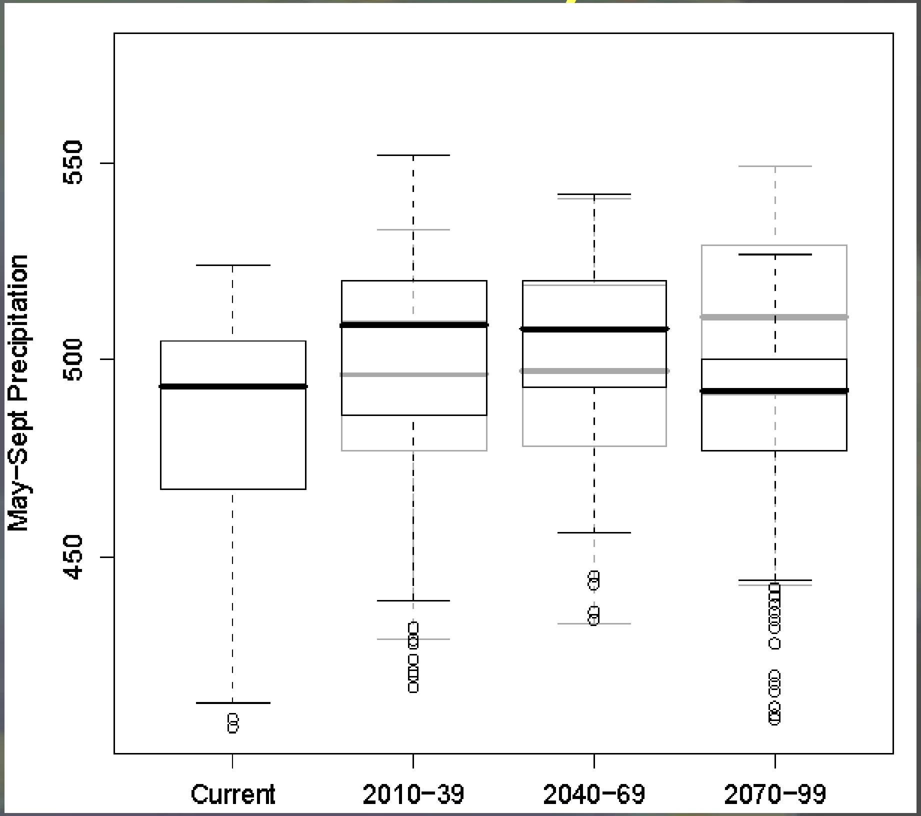
Black Ash "zone" and Habitat, 2000

Black Ash Habitat, 2100, Had Hi



Expected growing season changes (for northern Wisconsin)





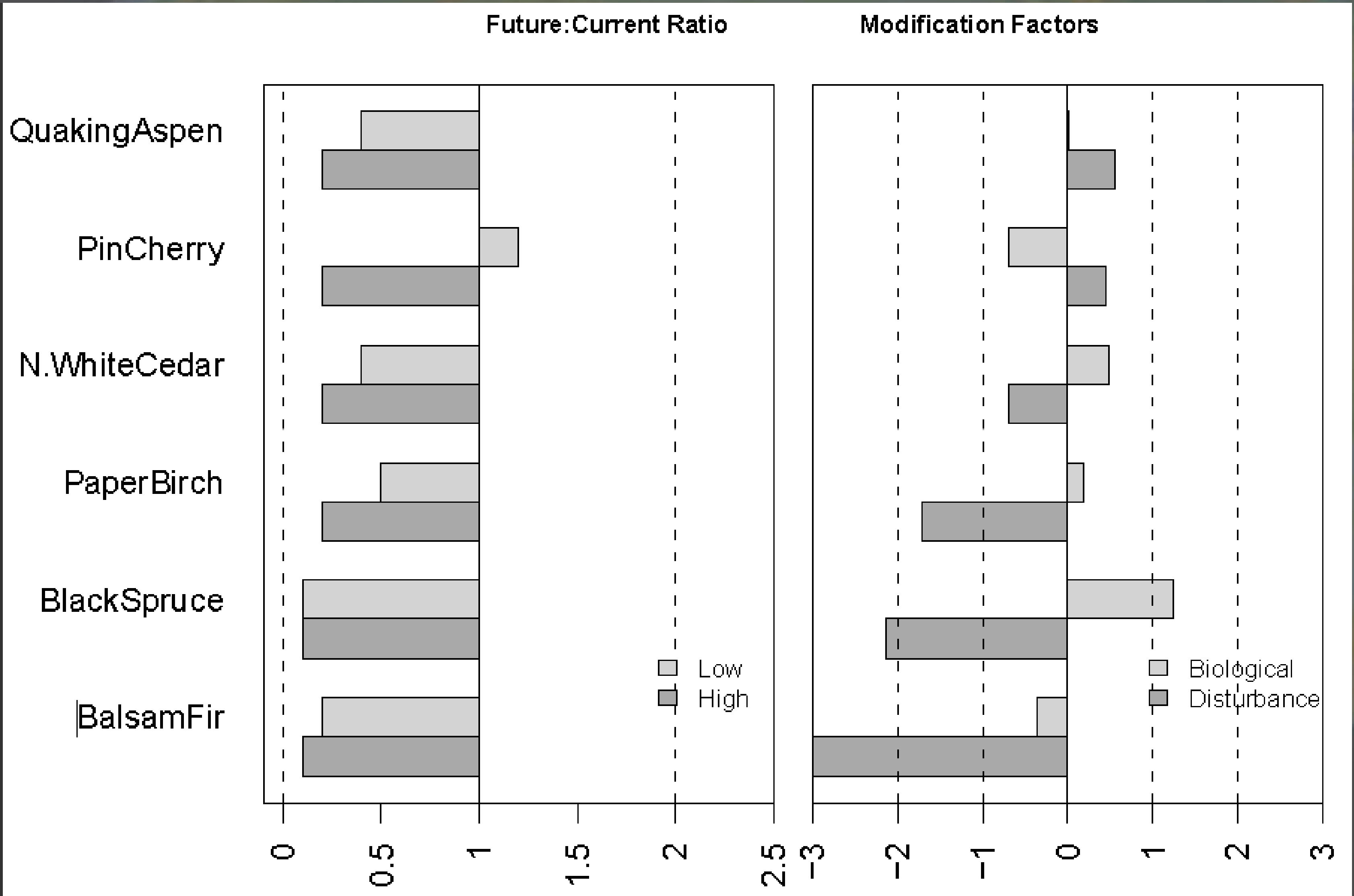
Growing season temperature higher and not much change in precipitation = more physiological stress on biota

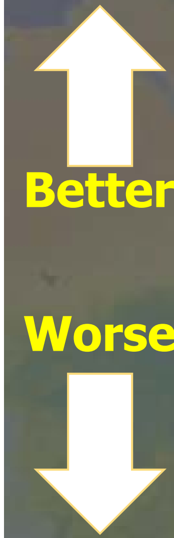
Potential Changes for Tree Species

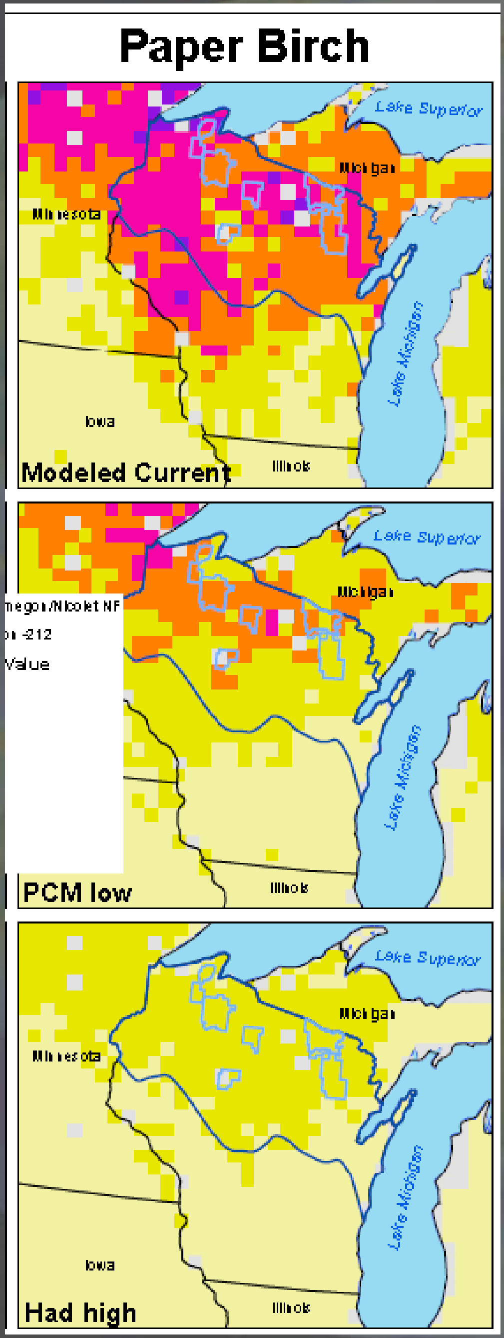
- Evaluated 85 species from the region
- Put in to 8 classes of impacts
  - Class 1: extirpated (2 species)
  - **Class 2: large decrease (6 species)**
  - Class 3: small decrease (14 species)
  - Class 4: no change (5 species)
  - Class 5: small increase (10 species)
  - **Class 6: large increase (23 species)**
  - **Class 7: new entry-high and low emissions (12 species)**
  - Class 8: new entry-high emissions (13 species)
- Score each species for modification factors to help managers interpret potential impacts and suggest adaptation strategies → Large tables!


1
2
3
4
5
6
7
8
Losers
Gainers
Migrators

Large Decreasers (Cl. 2)



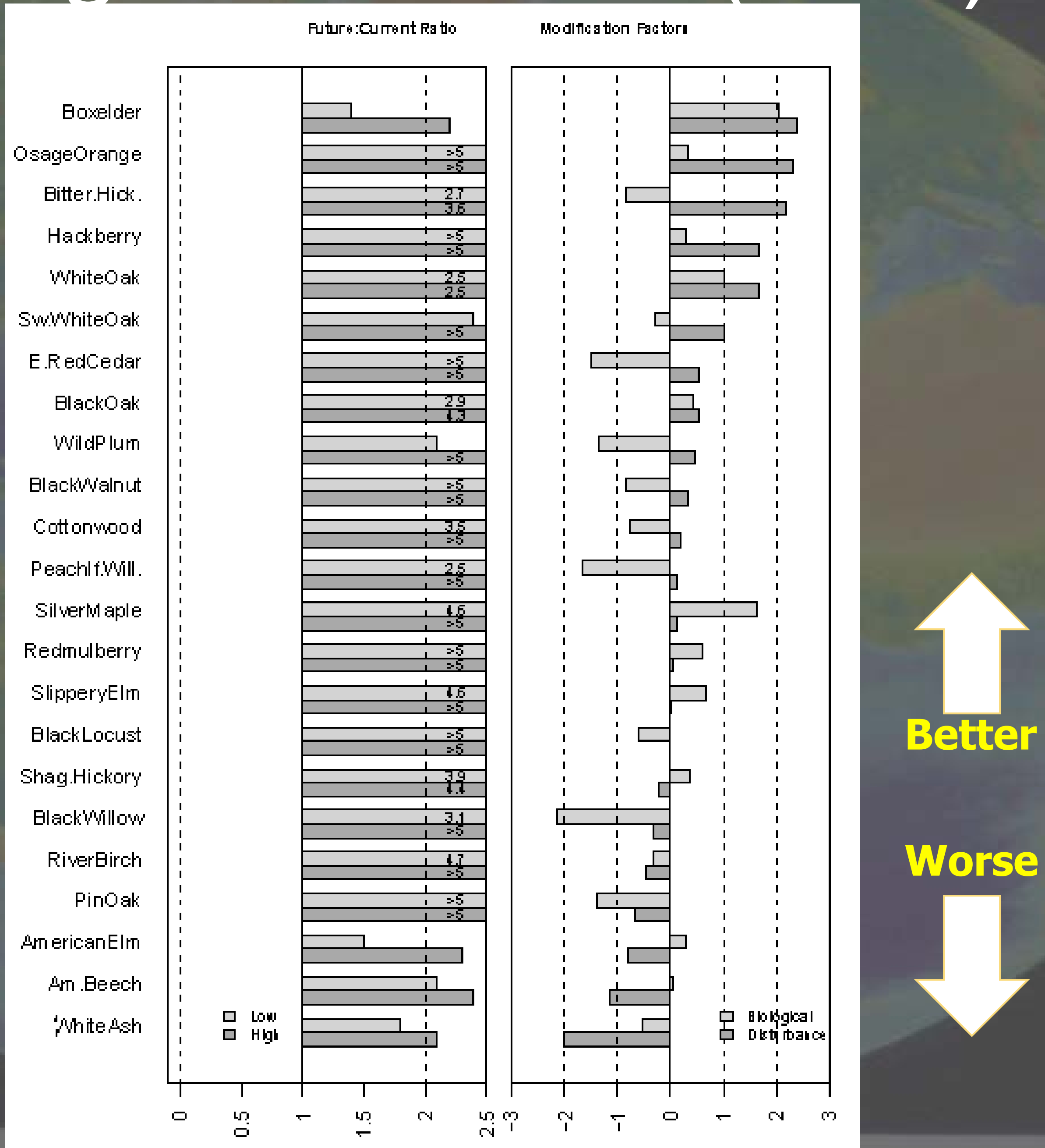


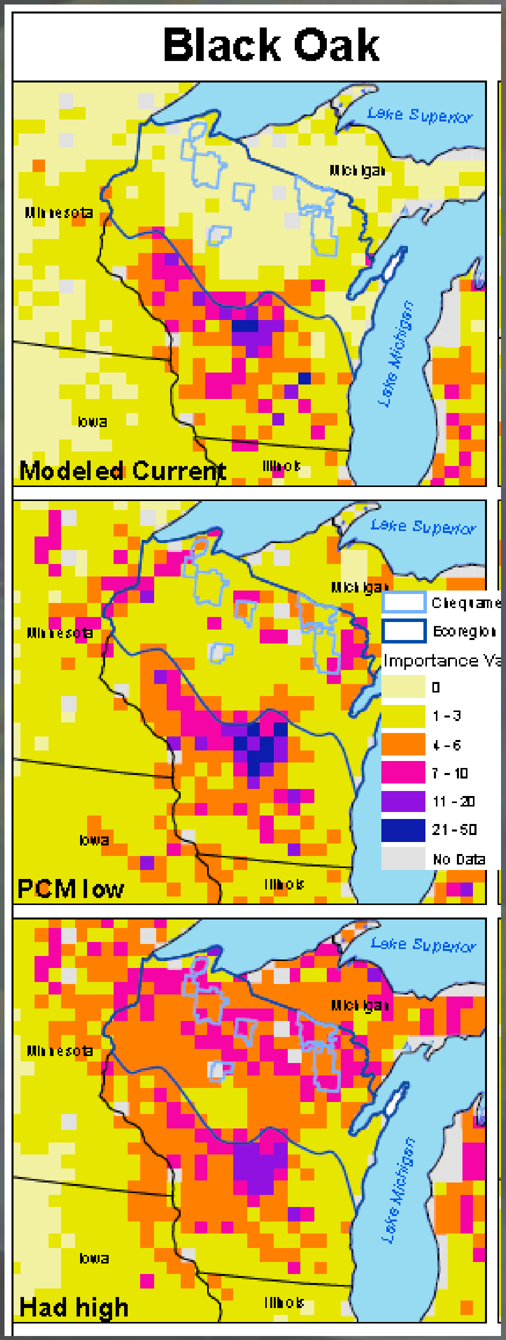


Class 2,
Large Decreasers

(especially under Had High scenario of climate change)

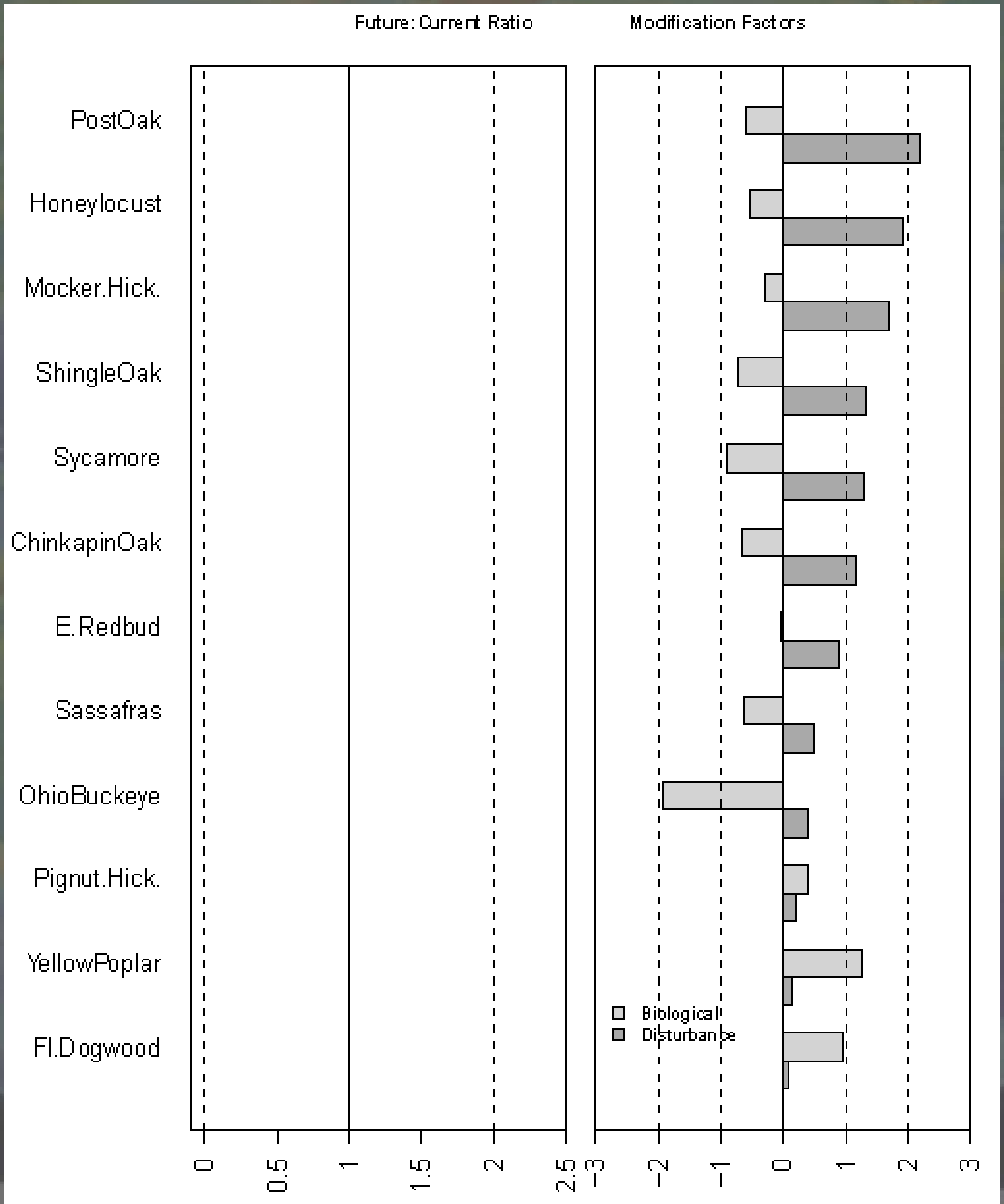
Large Increasers (Cl. 6)

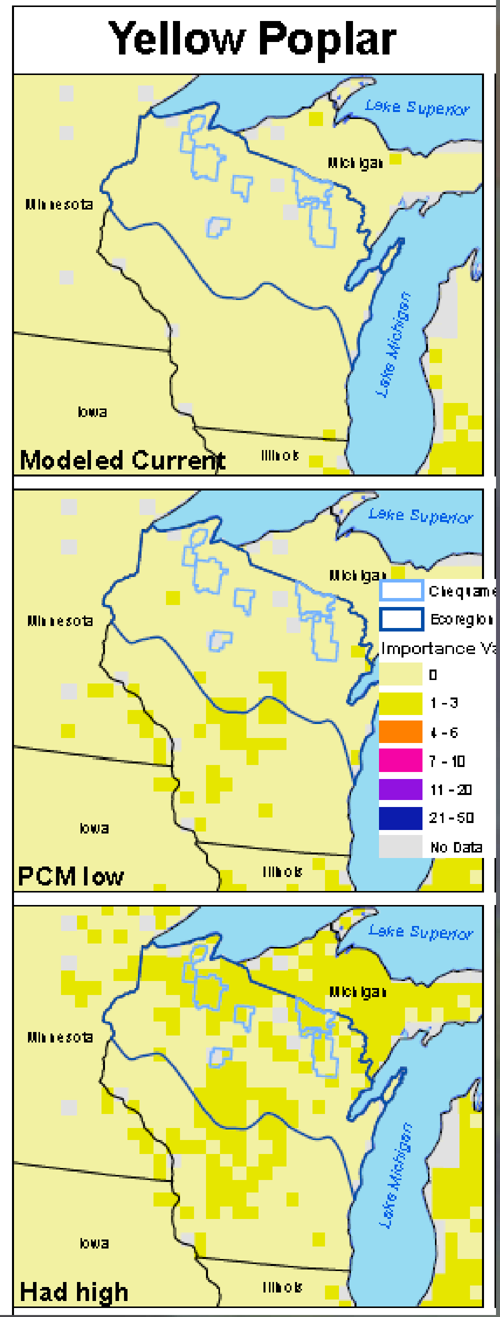




Class 6,
Large Increasers

New Migrants, low or high

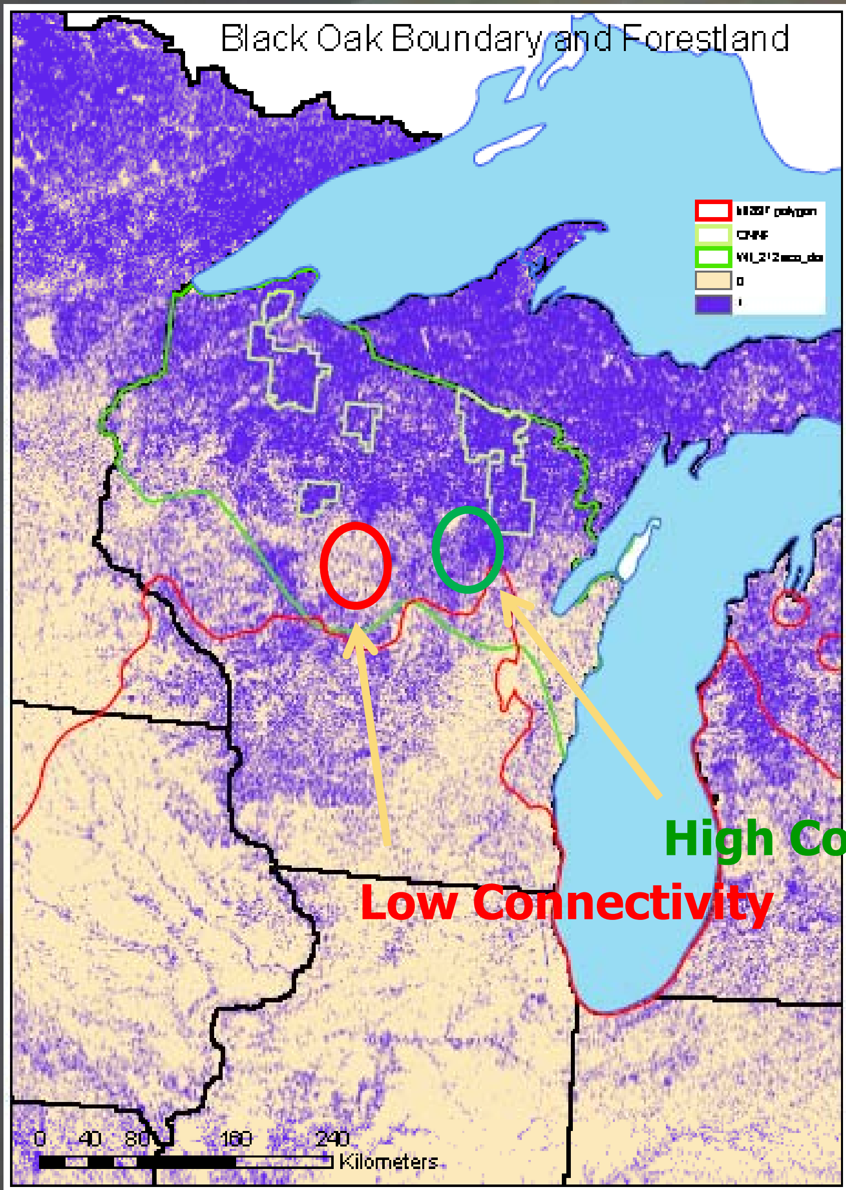


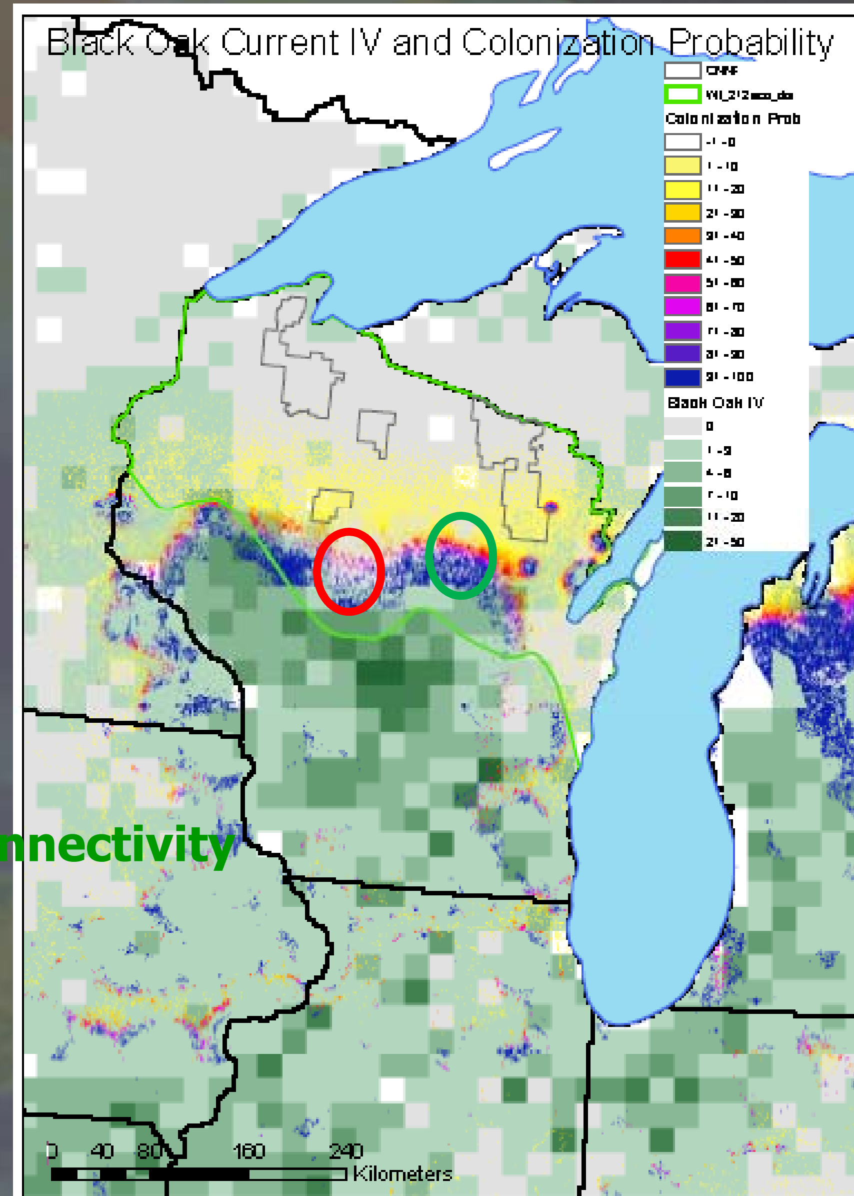


Class 7
New Migrants,

Any scenario
of climate change.

SHIFT (preliminary):Black oak potential migration by 2100





High Connectivity

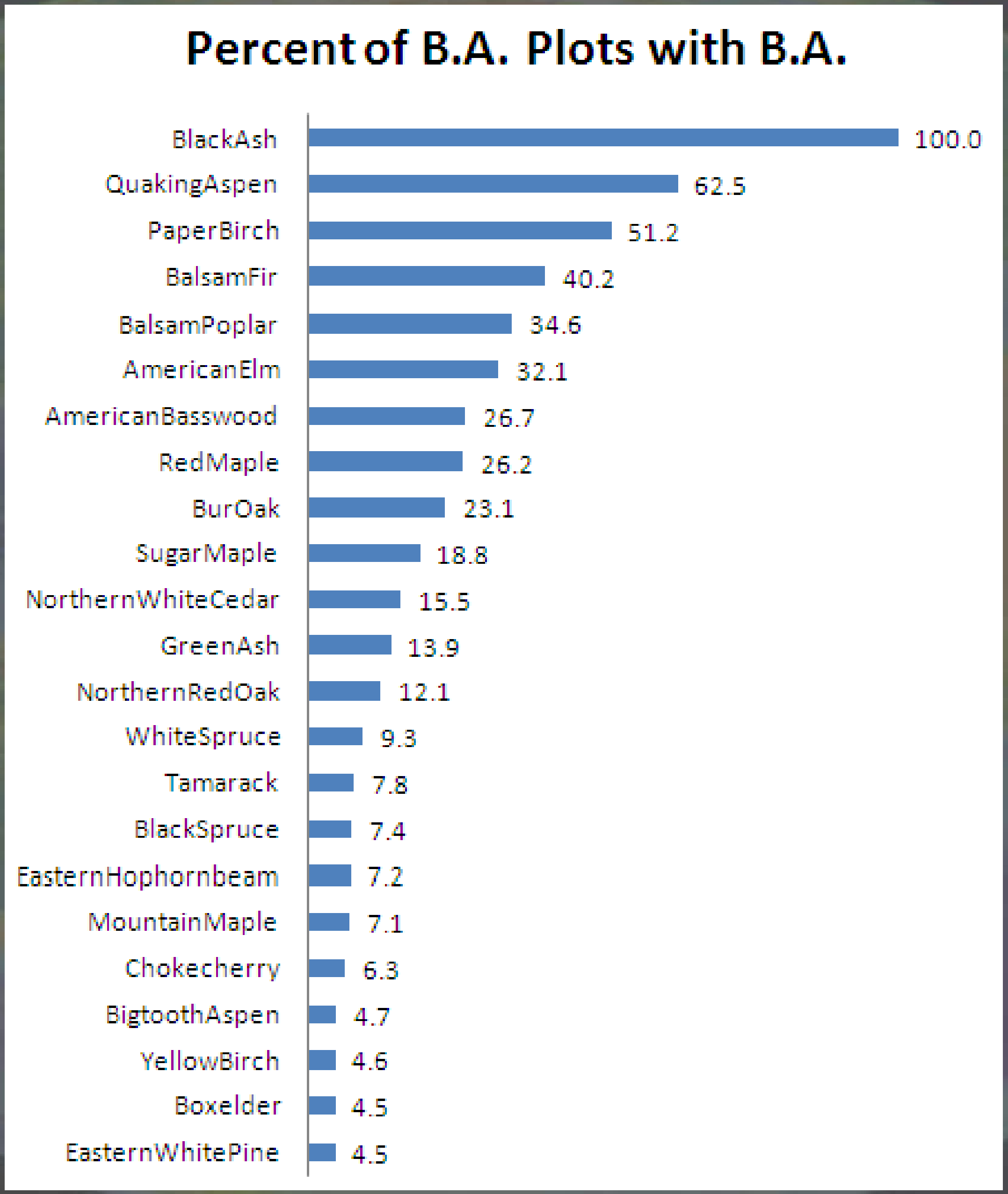
Low Connectivity

Forest Density (NLCD data 2000)

Shift (Preliminary)Output on Current Black Oak IV

Evaluate FIA plots for MN

- FIA from last periodic inventory, not precise locations
- Of 9427 plots, 2176 (23%) had black ash
- Of these, we evaluated 23 species co-occurring on >4% of the plots


Percent of B.A. Plots with B.A.
BlackAsh 100.0
QuakingAspen 62.5
PaperBirch 51.2
BalsamFir 40.2
BalsamPoplar 34.6
AmericanElm 32.1
AmericanBasswood 26.7
RedMaple 26.2
BurOak 23.1
SugarMaple 18.8
NorthernWhiteCedar 15.5
GreenAsh 13.9
NorthernRedOak 12.1
WhiteSpruce 9.3
Tamarack 7.8
BlackSpruce 7.4
EasternHophornbeam 7.2
MountainMaple 7.1
Chokecherry 6.3
BigtoothAspen 4.7
YellowBirch 4.6
Boxelder 4.5
EasternWhitePine 4.5

Species with High Potential to Replace Black Ash in the long term

- Already live with black ash, either in MN or in points south (OH or MI)
- Have potential to do well or at least OK under climate change – according to our DISTRIB models
- Have characteristics which allow it to do well under predicted outcomes of climate change – according to our ModFactors

6 Large Inc.

5 Small Inc.

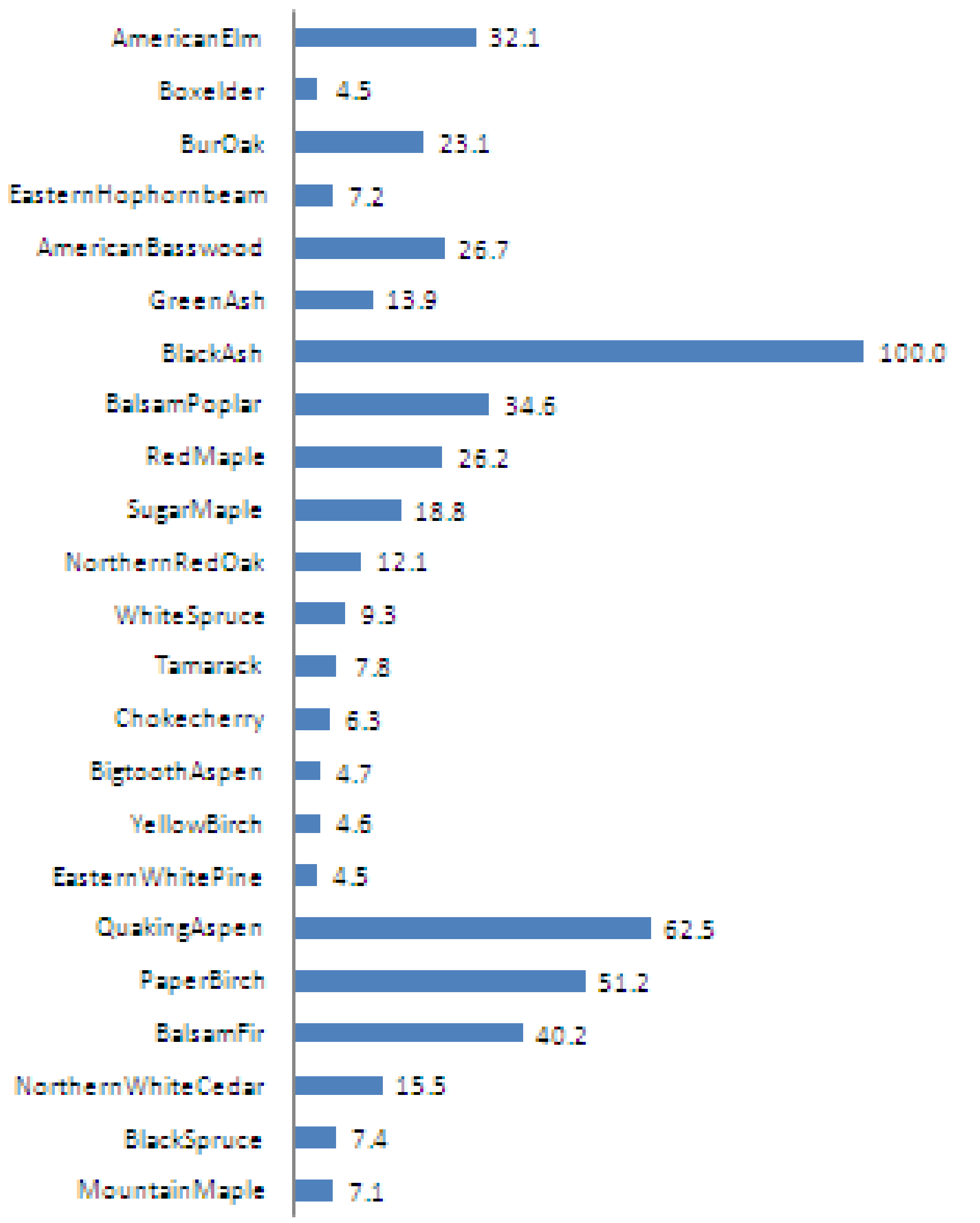
4 No Change

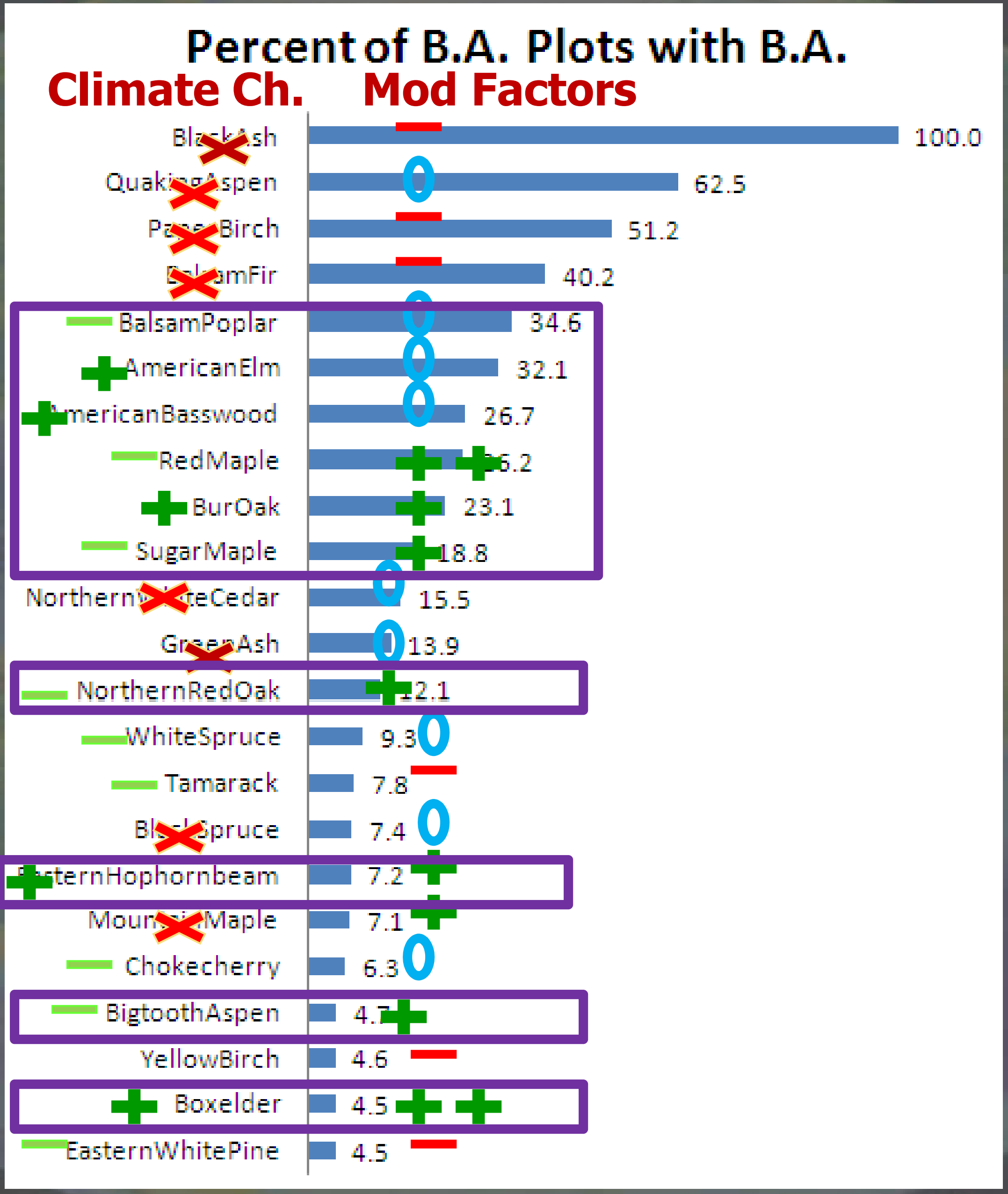
3 Small Dec.

2 Large Dec.

1 Extirpated

Percent of FIA with Black Ash





Percent of B.A. Plots with B.A.
Climate Ch.
Mod Factors
100.0
62.5
51.2
40.2
BalsamPoplar 34.6
AmericanElm 32.1
26.7
RedMaple
BurOak 23.1
SugarMaple 18.8
15.5
13.9
NorthernRedOak
WhiteSpruce 9.3
Tamarack 7.8
7.4
7.2
7.1
Chokecherry 6.3
BigtoothAspen
YellowBirch 4.6
Boxelder 4.5
EasternWhitePine 4.5

Some summary thoughts on ash and their replacements

- The short-term disturbance of EAB infestation will drastically overwhelm longer term impacts of climate change.
- Some of the species on list of potential replacements may seem ridiculous to consider as possible replacements. Some will be ridiculous but I encourage being generous in selecting species for further analysis and testing.
- Very subtle variations in topography and soils can greatly influence which species may be appropriate. Carefully control and map these factors to minimize mis-matching.

Management Implications

Potential **management implications** resulting from the above trends include:

- Encourage increased connectivity for increaser species.
- Evaluate potential for assisted migration.
- Encourage retention of refugia which may allow persistence of decreaser species.
- Prepare for additional costs likely required to maintain forest health due to increased stress and disturbances (e.g., insect pests, diseases, fire, ice, drought).
- Prepare for quite dramatic changes in some iconic north woods species!
- This is a terrific application for adaptive management!

Thank you!

For further information, consult our web atlas (www.nrs.fs.fed.us/atlas)

or contact me

(liverson@fs.fed.us)